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A BRIEF GENERAL ACCOUNT OF FOSSIL FISHES

THE TRIASSIC FISHES OF NEW JERSEY

BY

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PART I.

A Brief General Account of Fossil Fishes.

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SUMMARY.

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Province of Palæontology.—It having been suggested by the State Geologist that a presentation in untechnical language of the leading facts brought to light by the study of fossil fishes of New Jersey, together with some statement of their relations to the science of palæontology in general, would be of interest to a wide class of readers, the following section of the report has been prepared in accordance with that idea, detailed systematic descriptions being reserved for a separate chapter. Owing to the large number of persons whose attention has been attracted in one way or another to the remarkable fish remains found at Boonton and elsewhere, it is taken for granted that a lively interest exists in questions concerning their origin, their relations to extinct and modern forms, and the conditions under which they met their death and became preserved in the rocks. These and kindred topics it is our purpose to examine into in the following pages.

Probably everyone has some notion of what is meant by the term *fossil.* Strictly defined, fossils include the remains or traces of plants and animals that have lived during former periods of the earth's history, and whose remains or other indications have become preserved in the rocks. By the process of petrifaction, as it is called, the hard parts of animal bodies, such as the shelly covering of mollusks, crustaceans, echinoderms (sea-urchins, star-fish, etc.), or the internal skeleton of vertebrates, become replaced by mineral matter, all organic substances being converted into stone. Horney chitinous tissue undergoes a similar process; and certain other substances, such as vegetable matter, feathers, and in rare instances animal integument, become carbonized. But almost invariably the soft parts of dead bodies suffer decomposition either before or after burial in the preserving medium, thus leaving no traces in the rocks. It is only under exceptionally favorable circumstances that muscular fibre, dermal coverings, cartilage, or internal organs (such as the swim-bladder, walls of the intestinal canal, or egg-cases of cartilaginous fishes) have been preserved in recognizable condition. Nevertheless, conditions have sometimes permitted even the most delicate structures, such as insects' wings and impressions of jelly-fishes, to become retained in the soft mud, which afterwards became solidified. Localities famous the world over for the beauty and delicacy of their fossil remains are the lithographic stone quarries of Bavaria and the department of Ain, France. An inquiry into the conditions under which these deposits were laid down suggests with much plausibility that they represent filled-in lagoons of coral atolls.

It is worthy of remark that any investigation of fossil faunas takes into account all questions relating to the environment of the forms represented, the climatal and geographic conditions amidst which they flourished, their food, habits, migration, and genetic relations to other species. In a word, we have not only to consider the nature of organic remains which have become preserved in the fossil state, but must also reconstruct as accurately as possible the conditions that were operative during their lifetime, approaching them in the same manner as we would organisms of the present day. There is, therefore, no essential

difference between zoölogy and palæontology, it being evident, as Huxley has said, that "fossils are only animals and plants which have been dead rather longer than those that died yesterday." In the same way, palæichthyology, or that branch of natural science which treats of fossil fishes, extends our information from the existing fauna back to the earliest advent of vertebrate life upon our globe, and furnishes important information concerning the mode of succession and evolution of one of the great classes of back-boned creatures, the ground-type of that remarkable sequence of forms whose culmination is man.

Right at the outset we are brought face to face with the all-important and all-pervading doctrine of evolution, which forces upon us the truth that man is an organism amongst organisms, his origin and history being in nowise disassociated from the origin and history of other living creatures in the world. Let us once appreciate the intense human interest in the study of organic creation, once recognize the fact that geology reveals an elaborate history of organisms that have successively populated the earth from the time life first began, and it is clear that we enter upon a most fascinating field for research. Stripping palæontology of its more technical aspects, and looking upon it in a broad way as part of universal history, the foremost question we should seek to answer is, what general principles or laws are revealed by this history? Having ascertained what these laws are, we have next to interpret them philosophically, to ascertain the underlying cause or causes to which they are attributable. Do they of themselves afford a satisfactory summing up of the operation of natural processes which have always been at work in the world, and have the latter merely happened to behave in this manner—fortuitously, rather than in some other manner—or do they suggest a teleological explanation, in that they reflect the presence of ulterior plan and design?

In respect to these fundamental problems, palæontology vastly enlarges the material at our disposal for philosophical analysis, furnishing at the same time a most important aid and ally to cognate sciences like zoölogy and embryology; and the extent to which these sciences severally supplement one another is indeed remarkable. A word may be said to illustrate the truth of this

statement. Let us imagine the evidence of fossils to be excluded; and let the zoölogist, whom we may suppose is acquainted only with the modern fauna, be required to frame a theory of evolution. He will at once perceive that animals belonging to certain groups resemble one another more or less closely, but the groups themselves are widely separated; and, moreover, in some of them there exist wide gaps without any hint that they were ever filled or bridged over by intermediate forms. Holding in his grasp merely the ends of disconnected threads, how is the zoölogist to prove their continuity, how demonstrate that they have all diverged from a common strand? Is it not equally logical for him to maintain, under the assumed limitations, the doctrine of special creation, and deny that the most extreme types of variation are linked by common ancestry?

All the way from a quarter to half a century ago, before palæontology had made its great strides in advance, the conditions we have imagined were altogether real, and the lacunæ between genera, families and higher groups presented a difficulty which it appeared unreasonable to explain by an appeal to the imperfection of the palæontological record. On the one hand the doctrine of evolution required these gaps to be filled, on the other no evidence was forthcoming to show that they ever had been filled. An interesting anecdote is related of the elder Agassiz by one of his students, Professor A. S. Packard,[1] which illustrates the attitude of the great naturalist toward evolution in his latter years. At the close of a lecture on *Limulus,* the horseshoe crab, in which Agassiz advocated the view that it does not stand as an isolated form in creation, but is descended from the common stem of jointed animals, the master strode up and down in a state of evident excitement, and then, as Packard recalls, "remarked to us with one of his most genial smiles on his lips: 'I should have been a great fellow for evolution if it had not been for the breaks in the palæontological record.' We replied: 'But, Professor, see what great gaps have been filled by the recent discoveries of birds with teeth, and of Tertiary mammals connecting widely separated existing orders.'

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[1] Amer. Nat., vol. xxxii (1898), p. 164.

And then, with a few more words, which we do not distinctly remember, we separated. * * * And so it is, in youth the older naturalists of the present generation were taught the doctrine of creation by sudden, cataclysmic, mechanical 'creative' acts; and those to whose lot it fell to come in contact with the ultimate facts and principles of the new biology had to unlearn this view, and gradually to work out a larger, more profound, wider-reaching, and more philosophic conception of creation."

One of the chief merits of palæontology is that it has within recent years brought to light a wealth of facts which establish beyond dispute the continuity of life; and reveal, often in most circumstantial manner, how modern forms have been derived from antecedent forms, thus pointing to the conclusion that all animals and plants have sprung from a few primitive common ancestors. Though now all but universally accepted, the doctrine of evolution has been long in gaining ascendancy over the minds of men, and we are unable to declare that the newer views are at variance with the time-honored teleological explanation. Anyone who has read the late Professor Joseph Le Conte's "Evolution in Relation to Religious Thought," or Huxley's "Scientific Essays," or similar works, must have been convinced that the evolutionary hypothesis strengthens rather than weakens the claim that the workings of Nature are but the expression of a divine intelligence. There are those who maintain it is unnecessary to conjure up a *deus ex machina* to explain physical processes; and opposed to these there are others, rather in the majority we think, who declare that the whole system would be unintelligible without purposeful design—hence the assertion that the present order of things has come about as the result of hazard is contrary to our senses.

Palæontology may not hope to answer such vital and far-reaching questions as these; and yet it is not vain to expect from it light concerning the nature of the problems involved, and concerning our manner of viewing them. A very learned, very high-minded, very reverent palæontologist, for many years President of one of the sections of the French Academy, has thus apostrophized the sources of our information in regard to creation: "We cannot refrain from looking with curious admiration upon

the innumerable creatures that have become preserved to us from earth's early days, and calling them to life again in our imagination. We interrogate these ancient inhabitants of the earth whence they were derived: 'Speak to us and say whether you are isolated remnants, disseminated here and there throughout the immensity of the ages, without an order more comprehensible to us than the scattering of flowers over the prairie? Or are you in verity linked one to another, so that we may yet be able, amid the diversity of nature, to discover indications of a plan wherein the Infinite has stamped the impression of his unity?' The unraveling of the plan of creation, this is the goal toward which our efforts aspire nowadays." [1]

General Notions of Palæichthyology.—If this cursory review of the scope and province of palæontology has shown us anything, it must convince us that fossils are to be regarded as precious and authentic historical documents, which, in so far as they reveal important truths of nature, have vastly widened our comprehension of the organic world, and materially assist us in arriving at a unification of truth. What is true of fossils in general is true in particular degrees of fossil fishes, which we have now to consider somewhat more fully. Enough has already been said to show that the history of the group of fishes, the most primitive and most ancient of the vertebrate phylum, is of fascinating inter-

[1] Gaudry, A., Les Enchaînements du monde animal, etc., p. 3. Paris, 1883.

The continuation of this striking passage we shall do better to give in its original choice diction, as follows:

"Les paléontologistes ne sont pas d' accord sur la manière dont ce plan a été réalisé; plusieurs, considérant les nombreuses lacunes qui existent encore dans la série des êtres, croient à l' indépendance des espèces, et admettent que l'Auteur du monde a fait apparaître tour à tour les plantes et les animaux des temps géologiques de manière à simuler la filiation qui est dans sa pensée; d' autres savants, frappés au contraire de la rapidité avec laquelle les lacunes diminuent, supposent que la filiation a été réalisée materiellement, et que Dieu a produit les êtres des diverses époques en les tirant de ceux qui les avaient précédés. Cette dernière hypothèse est celle que je préfère; mais, qu' on l' adopte ou qu' on ne l' adopte pas, ce qui me paraît bien certain, c' est qu' il y a eu un plan. Un jour viendra sans doute où les paléontologistes pourront saisir le plan qui a présidé au développement de la vie. Ce sera là un beau jour pour eux, car, s' il y a tant de magnificence dans les détails de la nature, il ne doit pas y en avoir moins dans leur agencement général."

est. Apart from its intrinsic interest, the study of fossil fishes deserves a high place in our esteem on account of its having revealed certain fundamental truths, the importance of which can scarcely be overestimated. One of the most far-reaching of these in its later application is Louis Agassiz's discovery of the analogy between embryological phases of recent fishes and the geological succession of the class, which led him to a well defined conception of what is commonly called the "biogenetic law": *The history of the individual is but the epitomized history of the race.* In thus introducing the element of succession in time, Agassiz laid the basis for all more recent embryological work.

Another notable achievement arising from Agassiz's study of fossil fishes was the recognition of so-called "embryonic," "prophetic" or "synthetic" types, or such as combine in their structure peculiarities which afterwards became distributed amongst different distinct types, and are never again recombined. Differences in the organization of fossil fishes led Agassiz to discriminate between "lower" and "higher" forms, identical with the generalized and more highly specialized types of modern zoölogists. In the same way, Agassiz's "embryonic types," which he held to "represent in their whole organization early stages of the growth of higher representatives of the same type," are in many cases the ancestral types of the modern evolutionist.

A single illustration must suffice to show the application of these important generalizations derived from the study of fossil fishes. Agassiz, in the initial volume of his famous *Poissons Fossiles,* remarks more than once upon the fact that all fishes antedating the Lias have the extremity of the vertebral column deflected upward into a more or less prolonged caudal lobe, a condition technically described as *heterocercal.* Subsequently he observed that modern fishes exhibit a similar condition in their early stages, though it was left for the younger Agassiz to demonstrate that they faithfully reproduce ancestral characteristics. Adverting to this matter in his well-known "Essay on Classification," Professor Agassiz remarks: "In my researches upon fossil fishes, I have pointed out at length the embryonic character of the oldest fishes, but much remains to be done in that direction. The only fact of importance I have learned of late is that the

young Lepidosteus, long after it has been hatched, exhibits in the form of its tail, characters thus far only known among the fossil fishes of the Devonian system." [1]

Still more suggestive was the same author's comment upon the remarkable resemblance between the human fœtus in an early embryonic stage and those of the shark and skate; the similarity being so obvious that it may properly be claimed for higher animals, including man, that they pass through a "fish-stage," in which even gills and a rudimentary tail are present during the course of their early development.

It is hoped that the above general observations will serve to help the reader to a more or less definite idea concerning the scope and aims of palæontology, and the important influence exerted by it upon other lines of inquiry. Coming now more particularly to the question of fossil fishes, it remains to sketch in outline the general history of this class of vertebrates so far as it is revealed to us by the palæontological record, and finally to discuss the relations of those fishes occurring in the Triassic rocks of New Jersey to others that have preceded and followed them during the course of geological time. First of all, it is necessary to fix in our minds the chief divisions of the geological time scale, in order that the chronological succession of fossil forms may be kept clearly in view, and that we may form a more adequate appreciation of the time-interval between the Triassic fishes of New Jersey, and the Palæozoic, let us say, of adjoining States.

Geological Time Scale.—Most persons are probably aware that geologists divide the fossiliferous rocks into three principal series, known respectively as Primary, Secondary and Tertiary, or more familiarly as Palæozoic, Mesozoic and Cenozoic—these latter terms signifying "Ancient Life," "Mediæval Life" and "Recent Life." The term Archæan or Archæozoic is applied to primitive rocks of great thickness underlying the lowermost Palæozoic, none of which exhibit satisfactory evidence of organic life; if they formerly contained fossils, these have become entirely obliterated by metamorphic processes. The principal time-relations, "eras" or "ages," as they are called, are subdivided into various

[1] Contributions to the Natural History of the United States of America, vol. I. (1857), p. 115.

"systems" which are accepted everywhere as standard units of chronology; and the systems are further subdivided into "periods" and "epochs." It is important to observe the distinction between the historical categories expressing time-relations, and the corresponding division of the solid rocks into *systems, series* and *groups*. The stratigraphical column, that is to say, the entire rock series, is divided by means of unconformity and character of the fossils into "systems," as already observed, and these are in turn divided into series, groups and formations. The correspondence between this dual historical and stratigraphical classification is exhibited by the following schedule:

TIME.	ROCKS.
Eras	Systems
Ages	
Periods	Series
Epochs	Groups

For convenience of reference we may also be permitted to insert here a table showing the principal subdivisions of the stratigraphical column:

ERAS	SYSTEMS	PERIODS	LIFE
	Quaternary	Pleistocene	Man
Cenozoic	Tertiary	Pliocene Miocene Oligocene Eocene	Mammals the dominant class
Mesozoic	Cretaceous Jurassic Triassic		Reptiles dominant Birds appear Earliest mammals
Palæozoic	Permian Carboniferous Devonian Silurian Ordovician Cambrian	 Carboniferous: Upper, Lower Devonian: Upper, Middle, Lower	Amphibians the dominant class Fishes dominant Invertebrates still dominant Fishes appear All classes of invertebrates
Archæozoic	Algonkian Archæan	Huronian Laurentian	Indistinct evidence of life No evidence of life

Introduction and Succession of the Class of Fishes.—We may now proceed to take a brief survey of the introduction and progress of the class of fishes, as revealed to us by palæontological evidence, after which we shall be better prepared to understand the relations born by our local fossils to the group as a whole. It requires but a limited exercise of the imagination to picture to ourselves a world essentially like the one we inhabit to-day, but warmer, and tenanted only by lower groups of organisms; the land mostly in the form of scattered islands, destitute of grasses, deciduous trees and flowering plants, untrodden by any vertebrate creature; the sea without aquatic mammals, reptiles, fishes;

and the highest types of animal life consisting of forms related to the scorpion and king-crab. "Monsters in those days" there were none; life, such as it was, existed in profusion, but was of decidedly inferior organization, sluggish or sessile, mostly of small size, and rather uniformly distributed. But already, at as far distant a period as the oldest fossiliferous horizon, differentiation had been taking place, and all the great divisions of invertebrates had become definitely established. Finally it came to pass, in some manner and at some epoch—how and when we know not for certain—that the earliest chordate animals were introduced; that is to say, animals ancestral to modern vertebrates, probably cartilaginous and with only dermal folds for limbs, but craniate, and having an axial skeleton.

Some have imagined that the transition from invertebrates to chordates occurred through annelid worms, others through jointed animals (Arthropods), but here at least is a great gap as yet unfilled. All that we can affirm is that the Cambrian system has yielded hitherto no trace of forms which one may regard as standing in ancestral relations to chordates, and it is not until the Ordovician (or Lower Silurian) that we first meet with such creatures in the reality. These primitive, weird-looking organisms differ from fishes proper, and likewise from all other vertebrates, in the absence of paired limbs and of a lower jaw, as well as in the microscopical structure of their hard parts. Under the name of Ostracophores (literally "shell-bearing"), Professor Cope has placed them in a distinct class (*Agnatha*), thus sharply separating them from fishes proper. Nevertheless they approach in other respects very closely to fishes, and when we remember that the great group of Elasmobranchs (sharks and rays) has equally remote an origin, it will be clear that the history of vertebrate life on our globe extends over incredibly long periods of time.

One of the best known of these primitive vertebrates is that curious form to which Agassiz has given the name of *Pterichthys,* familiar to all readers of Hugh Miller's fascinating works. The first impression produced by these bizarre creatures upon the mind of their discoverer has been graphically described both by Miller and Agassiz. Says the latter: "This remarkable animal

has less resemblance than any other fossil of the Old Red Sandstone to anything that now exists. When first brought to view by the single blow of a hammer, there appeared on a ground of light-colored limestone [*i. e.,* sandstone], the effigy of a creature, fashioned apparently out of jet, with a body covered with plates, two powerful-looking arms articulated at the shoulders, a head as entirely lost in the trunk as that of the ray (or skate), and a long angular tail, equal in length to a third of the entire figure." [1]

Elsewhere when commenting on the singular fish fauna of the Old Red Sandstone he remarks: "I can never forget the impression produced upon me by the sight of these creatures, furnished with appendages resembling wings, yet belonging, as I had satisfied myself, to the class of fishes. * * * It is impossible to see aught more bizarre in all creation than the genus *Pterichthys;* the same astonishment felt by Cuvier in examining Plesiosaurs, I myself experienced when Mr. H. Miller, the first discoverer of these fossils, showed me the specimens which he collected in the Old Red Sandstone of Cromarty."

The genus *Pterichthys* (Fig. 1) is not represented in the rocks of this country, although a closely related form, *Bothriolepis,*

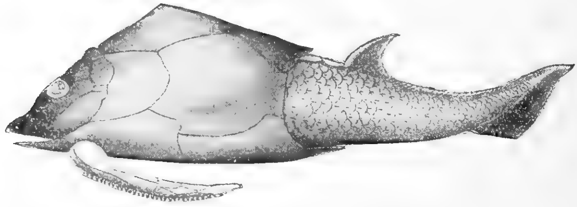

Fig. 1.

Pterichthys testudinarius Ag. Lower Old Red Sandstone; Scotland. Lateral aspect, restored by Dr. R. H. Traquair. × ½.

occurs in the Devonian of eastern North America and in Colorado. Other most curious and ancient Ostracophores are the forms known as *Cephalaspis* (Fig. 2), *Pteraspis* (Fig. 3) and

[1] Introduction to Hugh Miller's "Footprints of the Creator," p. xxi. American edition (Boston), 1850.

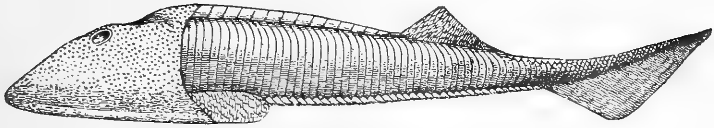

Fig. 2.

Cephalaspis murchisoni Egert. Silurian and Lower Devonian; Herefordshire. Lateral aspect, restored by Dr. A. S. Woodward. × ½.

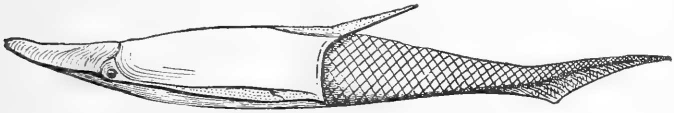

Fig. 3.

Pteraspis rostrata Ag. Lower Old Red Sandstone; Great Britain. Side view of partially restored fish. × ¾.

Tremataspis, together with the remarkable forms described within recent years from the Scottish Silurian, grouped by Dr. Traquair under the name of *Anaspida*. Of the above mentioned forms, only the genus *Cephalaspis* appears to have been common to both Europe and America.

Another primitive group of organisms found in association with Ostracophores in the Devonian of various parts of the world, and by many regarded as more or less akin to them, has received the name of Arthrodires, in allusion to a curious hinge-like device by which the body armor is movably united with the head-shield. Arthrodires are heavily armored fish-like vertebrates, the head and forward portion of the body being encased in a system of dermal plates, usually ornamented with fine stellate tubercles, and with cartilaginous axial skeleton. No indications have been found of paired fins, properly speaking, but a lower jaw occurs, suspended freely in the soft parts without being articulated to the cranium.

The typical genus is *Coccosteus* (Fig. 4), a comparatively small form, common to both sides of the Atlantic, and ancestral to the

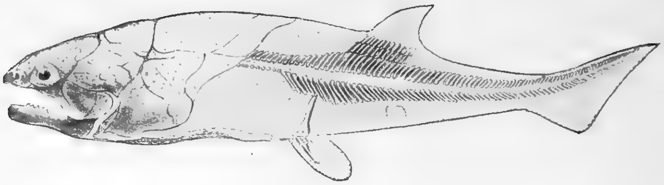

Fig. 4.

Coccosteus decipiens Ag. Lower Old Red Sandstone; Scotland. Lateral aspect, restored by Dr. R. H. Traquair. × ¼.

hugest of all Palæozoic fishes, *Dinichthys* and *Titanichthys,* which occur in the uppermost Devonian of Ohio and neighboring States. The length of these creatures has been estimated at upwards of fifteen or twenty feet, and the solidity of their armor-plating has never been surpassed amongst fishes. Over the back and head the bones were in places fully three inches thick, and exceedingly dense, though in smaller forms, of course, the armoring was lighter. Equally effective was their dental armature, *Dinichthys* having in the upper jaw a pair of beak-like incisors, behind which were formidable shear-teeth; and in the lower jaw a large and exceedingly powerful dental plate, likewise provided with a beak-like projection in front. It is evident that these creatures could not have been very mobile, owing to their cumbersome armor and lateral expanse of body, *Titanichthys* having a total width of about six feet; and it is further obvious from the character of sediments that they frequented the mouths of shallow estuaries, where they maintained probably a not very active existence. The characters already enumerated, such as the peculiar dermal plating, cartilaginous axis, and non-articulation of the lower jaw with the cranium, separate Arthrodires widely from modern bony fishes.

Considerable numbers of these armored creatures flourished throughout the Devonian, but became extinct at the close of that period without leaving any descendants. It is worth while to take note, in passing, of these and similar instances of extinction, which have in times past affected not only species and genera, but entire groups of organisms, sometimes without any discernible cause. No doubt in the majority of cases large groups become crowded out through the incessant and relentless struggle for

existence, weaker, less active, and less suitably adapted creatures giving way before their more successful competitors. It is a general rule, also, that overspecialized forms, or those whose habits and organization have responded so as to conform to particular external conditions, are liable to perish when these conditions change, through inability to readjust themselves in some other direction. But it would appear, further, that races of animals have a life-period of their own, comparable to those of individuals, or the nations of mankind. Just as the history of the latter resolves itself into periods of early development, dominant culmination—or "*Blüthezeit*," as the Germans call it—and final decadence; so species, genera and larger groups may be said to pass through various stages of immaturity, maturity and senility. Amongst old-age characteristics, whether of the individual or the race, must be reckoned an increased incapacity for variation, or decay of evolutional vigor; and after a certain point has been reached, this road leads on to extermination, either sudden or long-postponed. We shall have occasion to observe presently that there is a wide difference in longevity amongst various groups of organisms.

It will aid us to a graphic conception of the processes of evolution by likening them to a body rotating not always with uniform velocity in an ascending spiral, and giving off particles which partake of its own motion. At irregular intervals the centrifugal force is great enough to cause the particles to fly off in all directions, thus giving rise to what is known in palæontology as "expression points." [1] Now these particles, which we may call

[1] The following definition of expression points is taken from Smith Woodward's "Outlines of Vertebrate Palæontology" (Introduction, p. xxi.):

"All known facts appear to suggest that the processes of evolution have not operated in a gradual and uniform manner, but there has been a certain amount of rhythm in the course. A dominant old race at the beginning of its greatest vigor seems to give origin to a new type showing some fundamental change; this advanced form then seems to be driven from all the areas where the dominant ancestral race reigns supreme and evolution in the latter becomes comparatively insignificant. Meanwhile the banished type has acquired great developmental energy, and finally it spreads over every habitable region, replacing the effete race which originally produced it. Another 'expression point' (to use Cope's apt term) is thus reached, and the phenomenon is repeated. The actinoptergian fishes furnish an interesting illustration. The

variants, may be supposed to throw off in turn smaller particles, corresponding to species, which radiate in the same manner. Some will be precipitated at tangential extremes, halting finally when resistance overcomes their momentum; others will strike downwards in a retrograde path, and shortly disappear—these being the so-called degenerate species. And still others will be given an impetus in an upward direction, their movement continuing until they too are overcome by resistance. These last are the progressive species, and it is evident that only amongst this class can any persist and keep pace with fresh competitors that are constantly entering the field at higher levels. Certain ones that persist longer than others thus come to stand out in the changing complex as archaic types, their antique characters contrasting strangely with the remodeled order of things.

The parallelism we have imagined is not exact, but may serve as a graphic portrayal of the manner of succession and decadence of species and higher groups. One meets with a closer analogy in studying the history of languages, or of individual words in a single or in various languages. Every one knows that certain primitive roots, especially designations of essential objects and relations, have survived from early Aryan speech down to modern times; and innumerable cognate expressions exist side by side in European tongues derived from the Latin and Greek. Roots and stems, that is to say, the ground types, persist practically unchanged throughout all the vicissitudes and changing conditions of human progress. Variations, too, once firmly established, and favored by environment, are apt to persist indefinitely. Not only do words, idioms and figures of speech all illustrate the principle of evolution, but standards of pronunciation furnish

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earliest known member of this order *(Cheirolepis)* appears as an insignificant item in the Lower Devonian fauna, where crossopterygian and dipnoan fishes are dominant. When the latter begin to decline in the Lower Carboniferous, the suborder to which *Cheirolepis* belongs *(Chondrostei)* suddenly appears in overwhelming variety. By the period of the Upper Permian another fundamental advance has taken place—the *Protospondyli* have arisen; but only a solitary genus is observed among the hosts of the dominant race. In the Trias the new type becomes supreme, and at the same time the next higher suborder, that of the *Isospondyli,* begins to appear. This lingers on in the midst of the dominant *Protospondyli* during the Jurassic period, and then in the Cretaceous this and still higher suborders suddenly replace the earlier types and inaugurate a race which has subsequently changed only to an insignificant extent."

excellent examples of the working of the same governing force. Some of these are sufficiently significant as to be worth noting.

As has been aptly remarked by Professor Lounsbury,[1] the survival of ancient usage explains the existence among the uneducated of many pronunciations which, at a former period, were regularly employed by the educated. "The language of the illiterate is," this author observes, "to a great extent, archaic. It retains words and meanings and grammatical constructions which were once in the best of use, but have ceased to be used by the best. This is as true of pronunciation as it is of vocabulary and grammar. In this respect the archaic nature of the speech of the uneducated manifests itself in practices which would be little expected to exist. It sometimes affects the place of the accent. In our tongue it is generally popular usage which is disposed to lay the stress upon a syllable far from the end of the word. * * * Yet, curiously enough, this practice, based upon classical authority, lingers sometimes in the mouths of the uncultivated long after it has been abandoned by the cultivated. Readers of Milton are well aware that with him *blasphemous* is invariably pronounced *blasphe'-mous.* It was probably the general usage of the educated men of his time. Now no one pronounces it so save the unlettered. They remain faithful to the classical quantity, and are treated with contumely for it by such as deem it both their right and duty to be horrified by hearing *illustrate* pronounced *ill'ustrate.* Similar observations may be made of *contrary* and *mischievous.*"

It is apt to provoke a smile on hearing familiar words pronounced as if spelled *critter, nater, picter,* etc., instead of sounding the final *ture,* yet these are instances of inherited usage which two or three centuries ago was common in good society. A Londoner's pronunciation of the word *clerk* is another interesting survival, as is also the custom of replacing the sound of *e* by *a* in words like *certain* (vulgarly *sartin*), *service, servant, sermon* and *serpent.* Even *Jersey* was once pronounced *Jarsey,* as *clergy* was pronounced *clargy.* The reader will not fail to notice the close parallel existing between these cases of survival of ancient

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[1] The Standard of Pronounciation in English (New York and London, 1904).

mannerisms and the persistence of archaic types of animal life. The analogy may be developed a little further.

A tendency is to be noted nowadays toward accommodating the spoken word to the written, that is to say, there is purposeful adaptation along definite lines. This tendency is adverted to by Professor Lounsbury in following wise: "Colloquial or provincial speech will long continue to retain the old pronunciation. But even in those quarters they tend to die out with the increase of the habit of reading and the steadily waxing influence of the schoolmaster. Furthermore, in most, if not in all, of the instances where anomalies now exist, or once existed, it will be found that the current pronunciation represents a form of the word which at some time or at some place prevailed in writing as well as in sepaking. Illustrations of this are frequent. As good a one as any is furnished by the name itself of our language. We spell it *English;* we pronounce it *Ing'glish;* and we pronounce it so because by many it was once so spelled." And finally it is to be observed that all language is full of what Trench very happily calls the "fossil remains of metaphors"—that is to say, words which were once used to convey ideas by comparing them to something known, but the figurative sense of which is now forgotten. Examples of this kind will occur to the minds of every reader.

The object of the digression we have just made has been to bring the reader directly in contact with some of the fundamental facts with which palæontology has to deal, and to aid him to an understanding of them, or of their significance, through analogous examples. Returning now to our main theme, we may say finally of the Ostracophores and Arthrodires that they stand for divergent groups which branched off at a remote date from the parent stock, but failed to maintain their own as against later derivatives of the same stem. In the end their fate was identical, and, which is the more surprising, nearly contemporaneous with that of dominant groups of invertebrates during the Palæozoic, such as Trilobites and Eurypterids.

Elasmobranchs.—We have now to consider another very ancient, very primitive and very conservative group of fishes, one which has retained the essential features of its organization prac-

tically unchanged from the Silurian down to the present day. This is the great subclass of cartilaginous fishes, or Elasmobranchs (chimæroids, sharks and rays), by many supposed to be the ancestral stem from which all modern fishes have been derived, or at least which may be looked upon as representing most nearly the persistent ancestral condition of fishes. Amongst the salient characteristics of Elasmobranchs, by which they may be distinguished at once from all modern fishes, are to be noted (1) their cartilaginous skeleton; (2) shagreen integument; (3) heterocercal (asymmetrical) tail; (4) separate, slit-like gill-openings, metamerally arranged; (5) clasping organs in the male, and (6) various internal peculiarities. The skeleton is cartilaginous, sometimes calcified to a considerable extent, but never ossified, and never with dermal bones. The sturgeon is one of the few existing fishes which also has a cartilaginous skeleton and heterocercal tail—that is to say, one with a much produced superior lobe, instead of having the upper and lower lobes about equal; but it differs in its remaining characters, such as the absence of shagreen, of slit-like gills, presence of dermal bones, etc. Even a superficial examination of any shark or ray must serve to convince one that the characters enumerated above, taken in their entirety, are very trenchant, but there are numerous others besides these. For very full and minute accounts of the structure and habits of Elasmobranchs, it will be necessary to consult standard works on ichthyology, such as Dr. Günther's "Introduction to the Study of Fishes," the volume on *Fishes* in the "Cambridge Natural History," or Bashford Dean's "Fishes, Living and Fossil." The following general remarks, taken from the second of the works just mentioned, must suffice for the present discussion.

"The Elasmobranchs are for the most part active predaceous fishes, living at different depths in the sea, from the surface to nearly a thousand fathoms, and ranging from mid-ocean to the shallower waters round the coasts in almost every part of the world. Although typically marine, they sometimes ascend rivers beyond the reach of tides, and a few are permanent inhabitants of fresh water. They are most abundant in tropical and subtropical areas, where they also attain their greatest size, and are numerous in temperate regions, but there are some species which

are typically Arctic. None of them are small, and some of the sharks are the largest of living fishes. All are carniverous, but so diversified is their food that in different species it may range from other fishes of no mean size to mollusks, crustaceans and other invertebrates, or even to plankton. In their breeding habits the sharks and dog-fishes present many interesting features. * * * The majority of the sharks, dog-fishes and rays are viviparous, that is, the young are born alive; the rest * * * are oviparous, that is, the young are hatched out after the extrusion of the eggs."

Fossil remains of Elasmobranchs in the shape of detached hard parts, such as teeth, fin-spines and dermal tubercles, are known from a few Silurian localities, and are therefore amongst the earliest undoubted indications of vertebrate life. Fragments of this description become more numerous in the Devonian, and in the uppermost horizons of the system are found magnificently preserved skeletons, which exhibit in some instances even the microscopic structure of muscular tissues.[1]

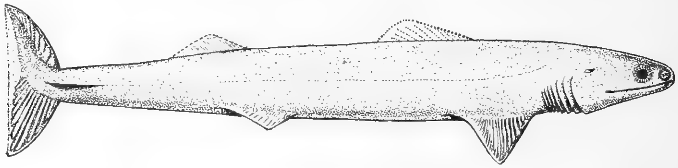

Fig. 5.

Cladoselache fyleri Newb. Cleveland Shale (Upper Devonian); Ohio. Lateral aspect, anterior dorsal fin-spine omitted. $\times 1/_{20}$. (From Dean.)

The best known of these primitive sharks is *Cladoselache* (Fig. 5), from the Cleveland shale of Ohio, an elongated, round-bodied form attaining a length of about five feet, with two dorsal fins and a very remarkable caudal extremity. The structure of the paired fins is extremely interesting in that it enlightens us as to the probable origin of vertebrate limbs from continuous dermal folds on either side of the body, just as the dorsal, caudal and anal fins are presumably derived from a continuous median fold. The teeth of *Cladoselache* are in the form of sharply

[1] Dean, B., Preservation of Muscle-fibres in Sharks of the Cleveland Shale. Amer. Geol., vol. xxx. (1902), pp. 273-278.

pointed cusps adapted for piercing, and the anterior dorsal fin appears to have been armed with a powerful spine similar to those described under the name of *Ctenacanthus*. This Devonian genus, as has been said, is the most primitive type of Elasmobranch yet discovered, and is regarded as the ancestral form from which a host of Carboniferous and most modern sharks are derived. A curious form intermediate between sharks and rays (*Tamiobatis*) is also known from the Devonian; and if we may assume dental plates to furnish a reliable clue, chimæroids (*Ptyctodus*) were present throughout this system in astonishing abundance.

During the Carboniferous the group of Elasmobranchs increased prodigiously in point of numbers, size and variety, and attained a world-wide distribution, but their rapid culmination which took place at the opening of this era was followed toward its close by an equally notable decline, approaching almost to the verge of extinction during the Permian. Some of the Carboniferous sharks were formidably armed, the largest fin-spines and most powerful crushing, cutting and piercing teeth known to the science of ichthyology having been developed during this era. An interesting generalized shark from the French Coal Measures (*Pleuracanthus*) combines within itself such a variety of synthetic characters as to justify the observation that "it is a form of fish which might with little modification become either a selachian, dipnoan, or crossopterygian." The long-lived group to which the Port Jackson shark (*Cestracion*) Fig. 6, belongs was exceedingly plentiful during the Carboniferous, and the number of species very

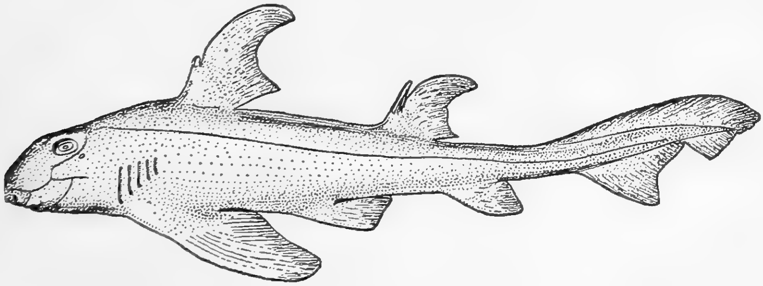

Fig. 6.

Port Jackson shark, *Cestracion philippi* (female). Recent; Australia. $\times {}^1/_{10}$. (From Dean, after Garman.)

extensive; but with the close of Palæozoic time the family became decadent.[1] The group of Elasmobranchs as a whole, however, began to flourish anew during the Mesozoic, gradually acquiring fresh evolutional vigor. It cannot be said to show signs of decadence in modern times, since it is represented in apparently undiminished numbers in the marine fauna of the present day. No members of the group have yet been discovered in the Newark rocks of New Jersey or New England.

Dipnoans.—The Devonian, which has justly been styled the "age of fishes," is remarkable for the introduction of two great subdivisions of Pisces, known commonly as Dipnoans and Ganoids, both of which are represented sparsely in the modern fauna. To the Dipnoans, or Lung-fishes, belong the "Barramunda" or *Neoceratodus* of Queensland, and two other genera, one of them (*Protopterus*) inhabiting African, and the other (*Lepidosiren*) South American rivers. As indicated by the common name of Lung-fishes, or *Dipneusti,* these fishes are remarkable for having pulmonary respiration, there being a functional lung (paired in the two last-named genera) in addition to the regular gills, thus enabling them to live out of water for considerable periods. The action of the lungs in conjunction with the gills furnishes a suggestion as to the manner in which air-breathing vertebrates have probably originated from gill-breathing, fish-like progenitors. Indeed, owing to the striking resemblances which Dipnoans present to amphibians in their vascular system and lungs, many have supposed that the former group was directly ancestral to the latter. The best modern opinion, however, is inclined to doubt that these resemblances are indicative of direct ancestral relations, regarding them rather as the outcome of physiological convergence, associated with adaptive and parallel modifications in structure, and due to the influence of a similar environment. It appears more probable that both Lung-fishes and amphibians have been derived from some primitive crossopterygian (ganoid) ancestor, not very divergent from the Elasmobranch stem, and subsequently became modified in certain respects along parallel lines.

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[1] Hay, O. P., The Chronological Distribution of the Elasmobranchs. Trans. Amer. Phil. Soc., vol. xx. (1901), pp. 63-75.

The habits of existing Lung-fishes are interesting. *Neoceratodus* lives all the year round in the water, there being no evidence that it ever becomes dried up in the mud, or passes into a summer sleep in a cocoon; and its paired fins, moreover, are useless for progression on the land. The following account of the habits of the remaining genera is taken from the "Cambridge Natural History":

"*Protopterus* has a wide distribution over the middle portion of the great African continent, * * * and is usually found in marshes in the vicinity of rivers. The tail is the principal organ of locomotion, and by its means the fish is capable of remarkably quick, agile movements. When slowly moving over the bottom of an aquarium the paired limbs are observed to move to and fro on opposite sides alternately in somewhat bipedal fashion. The limbs are useless for swimming, although it is possible that they may be helpful in creeping over the bottom, or in balancing, or as tactile organs. *Protopterus* is said to breathe by its lungs as well as by its gills, and to rise to the surface at short intervals to take in fresh air. In the dry seasons the marshes in which *Protopterus* lives become dried up, and to meet this adverse change in its surroundings the fish æstivates, or passes into a summer sleep, until the next rainy season brings about conditions more favorable to active life. Preparatory to this summer sleep, and before the ground becomes too hard, the fish makes its way into the mud to a depth of about 18 inches, and there coils itself up in a flask-like enlargement at the bottom of the burrow. * * * While encapsuled in its cocoon the fish is surrounded by a soft, slimy mucus, no doubt for the purpose of keeping the skin moist, and its lungs are the sole breathing organs, the air passing from the open mouth of the burrow through the hole in the lid directly to the mouth of the animal. * * * The length of the summer sleep naturally varies with the duration of the dry season, and probably it lasts on the average nearly half the year (August to December). The cocoons, embedded in an outward casing of hardened mud, have often been brought to Europe, and when placed in water of suitable temperature the long torpid *Protopterus* escapes from its prison in a perfectly healthy condition and resumes its partly branchial and partly pulmonary mode of breathing."

"*Lepidosiren paradoxa,* probably the only species of the genus, is confined to South America. * * * Of sluggish habits, the fish wriggles slowly about at the bottom of the swamp like an eel, using its hind limbs in an irregular bipedal fashion as it wends its way through the dense network of subaqueous plants. * * * Like other living Dipneusti, *Lepidosiren* rises to the surface to breathe. The intervals are, however, very variable, and no doubt depend on the relative purity or impurity of the water. Both expiration and inspiration are said to take place through the mouth. The snout is protruded on the surface and the creature expires. After being withdrawn for a moment the head is again projected and inspiration takes place through the partially opened lips. When the fish finally sinks a few bubbles of surplus air escape through the gill-clefts. * * * Like its African relative, the fish ceases to feed on the approach of the dry season and eventually hibernates at the dilated extremity of a tubular burrow, the entrance to which is plugged by a small

lump of clay perforated by several round holes. On the rising of the water at the next rainy season the *Lepidosiren* pushes out the plug and soon emerges from its burrow. The breeding season begins soon after the escape of the fish."

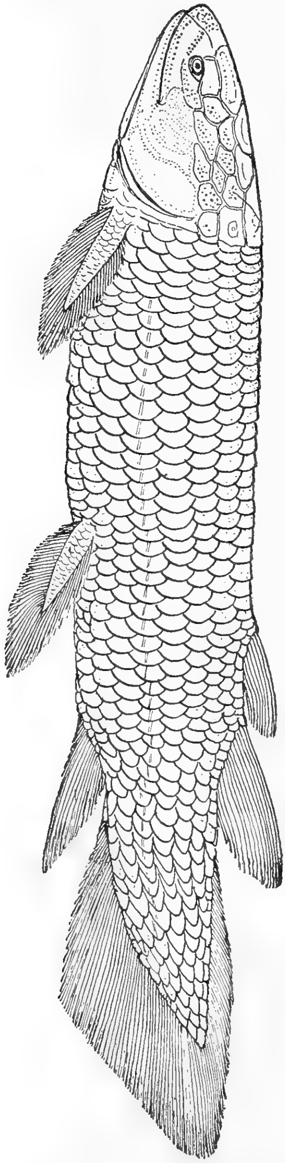

Fig. 7.

Dipterus valenciennesi Sedgw. and Murch. Lower Old Red Sandstone; Scotland. Lateral aspect, restored. × ¾. (From Dean.)

Pteraspis. Osteolepis. Holoptychius. Pterichthys.
Glyptolæmus.
Coccosteus.
Cephalaspis.

DEVONIAN FISHES.

Fig. 8 (From Lucas: "Animals Before Man in North America").

Concerning the origin of Lung-fishes as a group, it is further observed in the same work, that "it seems reasonable to look for their ancestors in the early Devonian *Crossoptergii* with acutely lobate fins, or, with greater probability, to some still more primitive *Crossopterygian* with simple, non-rhizodont teeth, capable by fusion of giving rise to massive tritoral plates." Throughout the Palæozoic this group of fishes formed a conspicuous feature of the vertebrate fauna, and although they appear to have attained their maximum development and specialization during the Devonian, they did not become entirely insignificant until near the close of the Trias. Teeth similar to those of the recent *Neoceratodus* are profusely distributed throughout Triassic rocks of the world, but none have been obtained thus far from the eastern part of the United States. It has been shown in a highly instructive manner by Dollo that the oldest known Lung-fishes, such as *Dipterus* (Fig. 7) and its associates, are the most archaic, and that their modern representatives have been derived from them by a series of retrogressive changes; or, in other words, the latter have much the same relation to the former as the degenerate sturgeons and paddle-fishes to their Palæozoic ancestors, the *Palæoniscidæ*. Owing to a fortunate abundance of material it is possible to select a series of genera, beginning with *Dipterus,* and terminating with modern forms, which illustrate the evolution of the group both in structure and in chronological sequence. Some of the more important structural modifications observable in the transition from the older to the recent genera are: (1) the gradual union of isolated median fins to form a continuous fin; (2) the conversion of a heterocercal tail into a symmetrically formed one; (3) the degeneration of the squamation, the thick, ganoid scales of the earlier types being replaced by thin, non-ganoid scales, or the skin becoming almost entirely naked; (4) a reduction in the number of cranial dermal bones and the loss of their original ganoid investment; (5) the suppression of the jugular plates, and (6) a reduction in the size of the opercular bones.

Ganoids.—The final and one of the most important contingent of the Devonian fauna is furnished by Ganoids, or enameled-scale fishes. These are divided into two orders, the so-called "fringed-finned" (*Crossopterygian*) and the "stout-finned" (*Ac-*

tinopterygian), from which the manifold variety of modern bony fishes has been derived. Both of these orders are represented in the Devonian, but the former greatly predominate, and the latter only begin to outstrip them during the Carboniferous. There is but little reason to doubt that the fringe-finned Ganoids gave rise to the class of amphibians, which makes its first appearance in the Carboniferous, this class in turn being ancestral to reptiles, and the latter to birds and mammals. The history of Crossopterygians is strikingly similar to that of Dipnoans, in that the majority of forms become extinct before the close of the Mesozoic, although in each case a few moribund survivors continue on to the present day. Only a solitary member of the order occurs in the Newark series of this State, a large form known as *Diplurus*, of which not more than three or four examples have come to light. A more particular notice of this form will be found in a subsequent section of this report.

Our attention may now be claimed by the important order of *Acanthopterygii*, which embraces not only large numbers of enameled-scale fishes, but all modern Teleosts, or so-called "bony fishes." The earliest and most primitive member of this order is *Cheirolepis*, which occurs in the Devonian of North Britain and Canada; but this is succeeded in the Carboniferous and Permian by a variety of forms, all exhibiting the same general features, and commonly grouped in the single family Palæoniscidæ. There is a marked resemblance between the members of this family and modern sturgeons and paddle-fishes; these latter, accordingly, can hardly be looked upon other than as late survivors of the ancient stem. Their similarity of structure is most evident in the structure of their fins, especially the heterocercal tail, and in the presence of characteristic plates (the so-called infraclavicles) in the jugular region. As for the degeneration of teeth and scales in recent forms, these seem to be characters of minor importance. Hence we may say that primitive sturgeons arose in the Devonian, and after giving off more specialized branches during the Palæozoic and Mesozoic, maintained a conservative existence down to the present day. Consequently, the longevity of the sturgeon tribe is no less remarkable than that of Lung-fishes, fringe-finned ganoids, and cartilaginous fishes like the Port Jackson shark.

Throughout the Devonian and Carboniferous, stout-finned Ganoids appear to have been represented by but this one group of primitive sturgeons. During the Permian, however, a typical "expression point" was reached, when a new suborder arose through various modifications of the skeleton. These latter involved atrophy of the upper lobe of the heterocercal tail, specialization of the fins, and loss of the infraclavicular plates already alluded to. Although represented by but a single genus (*Acentrophorus*) in the Upper Permian, the new suborder—known as *Protospondyli*—blossomed forth in surprising variety and attained world-wide distribution during the Trias, giving rise at the same time to a still higher suborder (*Isospondyli*). This last continued on during the Jurassic in the midst of the still dominant *Protospondyli,* until finally in the Cretaceous this and still higher suborders became supreme, practically monopolizing the seas, as do their descendants at this day.

To recapitulate briefly the history of the sturgeon tribe, we should bear in mind its introduction in the Devonian, its flourishing condition throughout the later Palæozoic, its giving rise in the Permian to a new suborder known as *Protospondyli,* and its persistence with only minor modifications until modern times. As for its Permian offshoot, this group acquired great importance during the Trias, giving forth still higher suborders, and these in turn leading to modern bony fishes. Inasmuch as the fish-bearing rocks of New Jersey are of Triassic age, it is not surprising to find the fauna largely composed of *Protospondyli.* The occurrence is to be expected here of sturgeon-like fishes, more highly specialized than the primitive *Palæoniscidæ,* and less so than the four modern genera of sturgeons and paddle-fishes; and this expectation is realized.

General Nature of the Boonton Fish Fauna.—Of the half dozen genera represented in the Triassic rocks of New Jersey, and likewise in New England, the one which is numerically the most abundant, and at the same time represented by the largest number of species, is that which has received the name of *Semionotus.* This form, with its abbreviate heterocercal tail, modified fin-structure and absence of infraclavicular plates, together with its ossified arches of the vertebral axis, falls within the definition

of *Protospondyli.* The next most important genus, *Catopterus,* and the nearly related *Dictyopyge,* have a less highly modified organization, and thus approach more closely to the primitive sturgeons, or *Palæoniscidæ.* *Acentrophorus,* though not occurring in the New Jersey Trias, is present in the Connecticut Valley region, and belongs with *Semionotus* amongst the *Protospondyli.* Hence, the afore-named genera, under which the majority of local species are comprised, may all be regarded as more or less primitive sturgeon-like fishes. Of the remaining genera, each of which is represented by a single species only, *Diplurus* is a member of the fringe-finned and *Ptycholepis* of the stout-finned or division of Ganoids. The Newark series is totally lacking in remains of sharks or lung-fishes, a circumstance which may possibly be associated with sedimentary conditions. These latter will be considered immediately.

For the benefit of many who may not be specially familiar with the teachings of palæontology, or who have but slight acquaintance with fossil fishes in general, it may be well to point out very distinctly that the Boonton fishes differ markedly from ordinary types of fishes now living. Consequently, the statement which one hears frequently asserted with more or less positiveness that this or that fossil specimen is exactly like a modern perch, or sun-fish, or other familiar form, springs from ignorance and careless observation. The nearest comparison with modern types that can be made is, as we have already explained, with the sturgeon, a comparatively rare form, and notably distinct from our common fresh-water fishes. One of the most obvious characteristics of the latter, as everyone knows, is that they have *bones.* The very name of "shad" is immediately suggestive of a fish "full of bones." That is to say, there is, first of all, a "back-bone," or ossified vertebral column, with stout spines above and below; secondly, there are well-ossified ribs, these being a conspicuous feature, and lastly, in many forms at least, there are numerous fine inter-muscular bones. The head also, in modern bony fishes, is well ossified. But none of the Boonton fossils exhibit these features, save only in some species the ribs and vertebral arches (but not the *centra* or body of the vertebræ) are imperfectly ossified.

Another very notable difference is that the Boonton fishes do not have round or cyloidal, over-lapping scales; but instead, these are rhomboidal, enamel-like and typically united by a peg-and-socket articulation. And again, we must take due note of the fact that the tails of the Boonton fish are very unlike those of modern Teleosts, or "bony fishes," the vertebral column projecting into the upper caudal lobe and making that lobe longer and larger than the lower lobe. The unsymmetrical or heterocercal caudal fin, and the presence of fine ray-lets or "fulcra" along the borders of all the fins are characters by which the fossil species may be told at a glance from the vast majority of recent forms.

Reconstruction of Physical Conditions.—An investigation into the nature of sedimentation over the Triassic area enables us to reconstruct more or less perfectly in imagination the former environment of the Boonton fish fauna, and to account with some plausibility for the sudden extinction and preservation of vast numbers of creatures.

Both in New Jersey and New England the inference may be drawn from a variety of evidence, such as geographical surroundings, composition of the sediments, presence of ripple-marks, abundance of land plants and similar indications, that the rocks of the Newark group were laid down under shallow-water conditions in proximity to the land. In the Connecticut Valley region the strata were clearly deposited in a sort of embayment, bounded on either side by eruptives of the mainland, and it is even possible to determine the current directions over part of this area, as has been done by Professor Emerson, of Amherst. As the tide rose and fell, alternately covering and leaving bare extensive mud-flats, huge reptiles, the like of which no longer exist, roamed in large numbers up and down the shore, searching their prey and leaving tell-tale footprints, which have been preserved from their day to this.

Little else but footprints bears witness to the existence of these weird creatures, a fact which offers a striking commentary on the imperfection of the palæontological record. Although for a long time regarded as imprints made by birds, it is now known that these are traces of reptiles belonging to the order of Dinosaurs, whose gait was bipedal. In New Jersey, also, similar tracks have

been found, though less plentifully, and on some slabs may be seen impressions of rain-drops that fell incredibly long ages ago. All these facts are of significance for our present purpose, but there are others more important. We know that deposition of Triassic sediments over both the areas under consideration was accompanied by great volcanic activity, and the question at once arises whether there may have been any connection between such phenomena and the sudden mortality of fishes on a large scale. An affirmative answer appears to us not only legitimate, but highly plausible.

If one inquires what are the reasons for believing that the mortality was accomplished suddenly and on an extensive scale, it may be pointed out that no other explanation can account for the remarkable abundance of these fish remains in beds of limited thickness; hence, the destruction must be attributed to some unusual cause or causes. Now, amongst the *possible* causes which are known to have produced similar results in other instances, those which proceed from volcanic and seismic disturbances acquire force by reason of the established contemporaneity of these agencies. The conditions which we are justified in supposing to have existed here were not such as involve the partial or total evaporation of land-locked waters, or irruptions from the outer sea into sheltered, more or less brackish inlets. Nor does the copious discharge of fresh water from the mouths of estuaries offer a likely explanation for so widespread a destruction of ichthyic life. To assume that these creatures perished from an outbreak of parasitic diseases would be a wanton hypothesis. There remains finally the pleausible conjecture of earthquake shocks and volcanic explosions—the two being closely related—shocks killing marine life by the violence of the concussion, and volcanoes either from the heat of the lava, or from the abundance of ashes and poisonous gases.

It has been repeatedly observed that earthquake shocks have been followed by the washing ashore of vast quantities of dead fish. The learned Greek geographer, Strabo,[1] for instance, men-

[1] The account given by Strabo *(Geog.* vi., 2, 11) of the destruction of fish life by submarine disturbances in the vicinity of the Lipari Islands, near Sicily, reads as follows:

tions the remarkable effects of earthquakes in ancient times, and gives a particular account of the upheaval of an island in the Ægean, parallel occurrences being the sudden formation of Monte Nuovo, near Naples, in 1538, and of a new island near Santorin, in 1707. All these considerations lend the color of plausibility to the hypothesis that either seismic or volcanic disturbances, or both together, stand in causal relation to the Boonton fish beds. Nevertheless, the means at our disposal do not permit us to push the hypothesis further, so as to arrive at a demonstration of the real cause or causes.

Progress of Palæichthyology.—Before closing this general account of the Triassic fishes of New Jersey, it may be of interest to some to take a brief retrospect over the history of that branch of natural science which is concerned with the investigation of fossil fishes. In so far as this class of organisms was one of the earliest to attract attention in the fossil state, it may be claimed that palæichthyology is coëval with the broader field of palæontology in general. The earliest mention of fossil fishes in litera-

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"Posidonius says that at a time so recent as to be almost within his recollection, about the summer solstice and at break of day, between Hiera [now called Volcano] and Euonymus [one of the Lipari, not certainly identified], the sea was observed to be suddenly raised aloft and to abide some time raised in a compact mass, and then to subside. Some ventured to approach that part in their ships; they observed the fish dead and driven by the current, but being distressed by the heat and foul smell were compelled to turn back. One of the boats which had approached nearest lost some of her crew, and was scarcely able to reach Lipari with the rest, and they had fits like an epileptic person, at one time fainting and giddy, and at another returning to their senses; and many days afterwards a mud or clay was observed rising in the sea, and in many parts the flames issued, and smoke and smoky blazes."

A chapter in Pliny's *Natural History* (ii., 89), which is devoted to islands that have been uplifted from beneath the sea, contains an altogether similar account: "Opposite to us, and near to Italy, among the Æolian isles, an island emerged from the sea; and likewise one near Crete, 2,500 paces in extent, and with warm springs in it; another made its appearance in the third year of the 163d Olympiad (B. C. 125) in the Tuscan gulf, burning with a violent explosion. There is a tradition, too, that a great number of fishes were floating about the spot, and that those who made use of them for food immediately expired."

Other well-known instances of the sudden destruction of fish life in enormous quantities are those following the destruction of disturbances at Vera Cruz in 1742, and at Sumatra in 1755. The recent history of tile-fishes off the coast of Massachusetts is also extremely suggestive.

ture is attributed to Xenophanes of Colophon, who flourished towards the end of the sixth century of the pagan era, and was founder of the Eleatic school of philosophy. Only a few fragments of his writings have come down to us, but he is reported by later authors to have commented upon the remains of fishes and other animals in the fossil state, their occurrence having been explained by him in a most sagacious manner. He not only inferred from them the former transgression of the sea over the land, but also the possibility of future submergence, with accompanying extinction of all forms of terrestrial life.

Xanthus and Herodotus, of the fifth century B. C., entertained similar opinions concerning the nature of fossils, and it is evident from the writings of numerous Greek and Roman authors, both prior to and after the beginning of the Christian era, that petrified remains attracted considerable attention. The Emperor Augustus even possessed a collection of fossil bones. At a later period, however, the views of Aristotle, especially those relating to spontaneous generation, exerted a baneful influence upon the interpretation of nature, it being assumed that living creatures could spring into existence and acquire of themselves almost any conceivable shape; and if this were possible for living creatures, so also might it be possible for mineral matter to assume endless variety of form. In consequence, fossils were for a long time regarded as fortuitous aggregations which had been formed within the rocks, or had become moulded on the spot through occult agencies, or through the medium of a *vis plastica*. A rival theory that fossils were the remains of bodies which had been overwhelmed by the Scriptural deluge, afterwards becoming preserved in the rocks, also engrafted itself firmly upon the popular imagination.

Leonardo da Vinci, one of the most original and versatile geniuses the world has seen, and Girolamo Fracastoro, his younger contemporary and fellow-countryman, were among the first to ridicule the prevailing misconceptions of their time (early part of the sixteenth century), and to point out the true nature of fossils in convincing manner. Those interested in the development of geological and palæontological science during the formative period of their history will find excellent accounts in Sir Charles

Lyell's "Principles of Geology," in von Zittel's "History of Geology and Palæontology," in Andrew Dickson White's "History of the Conflict of Science with Theology," in Huxley's "Essay on the Progress of Palæontology," and numerous similar works.

As an example of the persistence with which the minds even of learned men lent themselves to absurd and impossible theories, instead of heeding the sagacious explanations of Fracastoro and others, we may point to one of the early occasions when a scientific body was addressed on the subject of fossil fishes. An instance is furnished by J. P. Maraldi's communication to the French Academy on Veronese fossils, an abstract of which is published in the proceedings of that society for the year 1703.[1] Some general comments on the appearance of Bolca fishes, and others from Sicily and Phœnicia, are followed by suggestions concerning their origin, which at the present day seem most curious.[2]

Fossil fishes from the Monte Bolca locality, near Verona, also furnish the subject for an address before the Royal Irish Academy[3] towards the close of the eighteenth century, this being the earliest paper in English devoted to this class of remains. The discovery of fossil elephant remains in various parts of Europe and America gave rise to animated discussions of gigantology;

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[1] Hist. de l' Acad. Roy. des Sciences, année 1703, pp. 22-24. Paris, 1720. Consult also G. Astruc's "Histoire naturelle de la Province de Languedoc," chap. x. Paris, 1757.

[2] The passage may be quoted as follows: "Qui peut avoir porté ces poissons et ces coquillages dans les terres, et jusques sur le haut des montagnes? Il est vraisemblable qu' il y a des poissons souterrains comme des eaux souterrains, et ces eaux, * * * s' élevent en vapeurs, emportent peut-être avec elles des œufs et des semences très-légères, après quoi lorsqu' elles se condensent et se remettent en eau, ces œufs y peuvent éclorre, et devenir poissons ou coquillages. Que si ces courants d' eaux déjà élevés beaucoup au-dessus du niveau de la mer viennent * * * enfin à abandonner de quelque manière que ce soit les animaux qui s' y nourissoient, ils demeureront à sec, et envelоppés dans les terres, qui en se pétrifiant les pétrifieront aussi. Ces eaux elles-mêmes peuvent se pétrifier après avoir passé par de certaines terres, et s' être chargé de certains sels. Si toutes les pierres ont été liquides, comme le croyent d' habiles physiciens, cette espèce de système en est plus recevable."

[3] Graydon, G., On the Fish Enclosed in Stone of Monte Bolca. Trans. R. Irish Acad., vol. v. (1794), p. 281.

these bones being regarded by many as remains of human giants, the most famous specimen passing for the actual skeleton of *Teutobochus rex*. But it would prove altogether too lengthy a task for the limits of the present article to sketch even rapidly the history of this branch of natural science since the time of Linné and Artedi, the two great Swedish naturalists with whom the scientific study of fishes properly begins. It is to be noted, however, that very few contributions can be claimed to have materially advanced the science of palæichthyology prior to the time of Louis Agassiz, whose well known *"Poissons Fossiles"* constitues even to this day the most valuable repository of information we have on the whole subject.

In Agassiz's monograph are enumerated more than one thousand species of fossil fishes, the greater part of which are carefully described and excellently illustrated. The publication of this work marked an epoch, not only in palæontology, but general zoology as well, since one of its most brilliant results was the discovery of certain fundamental laws, a knowledge of which has aided wonderfully in strengthening the doctrine of evolution. Without doubt the most far-reaching of these in its consequences is the analogy which he pointed out between the embryonic phases of recent fishes and the geological succession of the class; whence followed the generalization, "The history of the individual is but the epitomized history of the race." Another notable result was the recognition of his so-called prophetic or synthetic types, or such as embrace features in their organization which afterwards become distributed amongst various groups, never again to be recombined. Yet more fruitful was Agassiz's insistence that the comparative anatomy of a group, including its palæontological record, should be studied in connection with the comparative embryology of the same; since, as he maintained, "the results of these two methods of inquiry complete and control each other."

Since the time of Louis Agassiz the scientific investigation of fossil fishes has made steady and most satisfactory progress. The ichthyic faunas of different horizons and localities are known in many cases almost as well as those of modern regions, and details of structure have been worked out in the most minute and painstaking manner. Our knowledge of the history of this

class of vertebrates has been vastly extended, and lines of descent have become revealed which afford new and precious insight concerning the inter-relations of different groups. If it was possible for Agassiz to reconstruct accurately the entire skeleton of a fish from a single scale, it is possible for us now to treat whole faunas in much the same way, since we are able to trace their origin, migrations and genetic relations—in many cases at least—and on bringing all these facts together, to observe the progress of evolution taking place, as it were, before our eyes.

Contributions to our Knowledge of American Triassic Fishes.—We must now turn from this imperfect survey of the scope and progress of the science to an equally rapid consideration of the work that has been done on American Triassic fishes. As early as the first decades of the preceding century the pioneers of American geology became interested in the fossil fishes and reptilian foot-prints of the Connecticut Valley sandstone, several communications in regard to them having been furnished by Hitchcock,[1] Silliman,[2] Mitchell[3] and Dekay.[4] They were also brought at an early date to the attention of scientists abroad, Brongniart, Agassiz, Lyell and Egerton having successively commented upon them during the first half of the century. But it is to the Redfields, father and son, who wrote between 1837

[1] Hitchcock, E., Discovery of Fossil Fish. Amer. Journ. Sci., vol. iii. (1821), pp. 365-366. *Ibid.*, vol. vi. (1823), p. 43. Final Report on the Geology of Massachusetts, vol. ii. (1841), pp. 458-525.

[2] Silliman, B., Miscellaneous Observations, etc. Amer. Journ. Sci., vol. iii. (1821), pp. 216, 365.

[3] Mitchell, S. L., Observations on the Geology of North America. 1818.

[4] Dekay, J. E., Fossil Fishes, in "Zoölogy of New York, or the New York Fauna" (Part iv., Fishes, pp. 385-387). Albany, 1842. Also an unpublished paper read before the Lyceum of Natural History of New York, noticed by J. H. Redfield in the Annals of the Lyceum, vol. iv., 1848.

The titles of these papers, with a single exception, are given by Dr. O. P. Hay in his Bibliography and Catalogue of the Fossil Vertebrata of North America, published in Bulletin No. 179 of the United States Geological Survey (1902). The exceptional paper is the posthumous report of John H. Redfield, published in part by Professor Newberry in his Monograph on the Fossil Fishes and Fossil Plants of the Triassic Rocks of New Jersey and the Connecticut Valley (1888). American vertebrate palæontology properly begins with the description in 1787, by President Thomas Jefferson, of mastodon remains from Virginia, followed a few years later by descriptions of the bones of *Megalonyx*, a gigantic sloth.

and 1857, that we are indebted for the first really satisfactory and detailed account of the Triassic fish-fauna of this country, these two having described nearly all the important species. Their results are embodied in ten contributions, eight by William C. Redfield, the elder, and two by John R., the younger; and they also brought together a valuable collection, which unfortunately has not been preserved in its entirety.

Some detached notices in regard to Triassic fishes appear also in the writings of Ebenezer Emmons,[1] accompanied by a few figures, but it was reserved for Professor John Strong Newberry to prepare the most elaborate and, on the whole, most satisfactory account of this fauna which we possess. His Monograph, which includes not only fossil fishes, but also fossil plants of the eastern United States, embodies a vast deal of painstaking and conscientious labor, carried on during the latter part of an active career. Since Newberry's time but little has been added to our knowledge of American Triassic fishes. An important memoir on the genus *Semionotus,* by Dr. E. Schellwien,[2] of Königsberg, appeared in 1901, in which some details and illustrations are given of two previously known species. Dr. George F. Eaton,[3] of Yale University, has also furnished brief accounts of several familiar forms, but pointing out a number of anatomical characters which had been previously overlooked. A supposed new species of *Semionotus* was described by the able collector, S. W. Loper,[4] in 1893, under the name of "*Ischypterus newberryi,*" and another doubtful species, which received the name of "*Ischypterus beardmorei,*" was illustrated some years later in a popular magazine by Mr. J. H. Smith,[5] formerly of the Montclair High School. More recently a detached dermal spine

[1] Emmons, E., Geological Report of the Midland Counties of North Carolina, 1856.—Report of the North Carolina Geological Survey. Agriculture of the Eastern Counties, together with Descriptions of the Fossils of the marl beds. Raleigh, 1858.—Manual of Geology, second edition. New York, 1860.

[2] Schellwien, E., Ueber Semionotus Ag. Schriften der Phys.-Oekonom. Gesellsch. zu Königsberg i. Pr. (1901), p. 34, pl. i-iii.

[3] Eaton, G. F., Notes on the Collection of Triassic Fishes at Yale. Amer. Journ. Sci., ser. 4, vol. xv. (1903), pp. 259-268, pl. v., vi.

[4] Loper, S. W., On a new Fossil Fish. Popular Science News (1893).

[5] Smith, J. H., Fish Four Million Years Old. Metropolitan Magazine, vol. xii. (1900), pp. 498-506.

from the Lower Trias of Idaho, apparently belonging to *Asteracanthus,* has been described by H. M. Evans[1] as a new species of *Cosmacanthus.* This last-named species is the only ichthyodorulite yet recorded from the American Trias, and the total absence of Elasmobranch remains in the eastern area may be regarded, so far as the evidence goes, as strenghtening our belief that these sediments were deposited under brackish water conditions.

One other western locality furnishing fossil fishes of supposed Triassic age is worthy of brief mention in this connection. During the years 1879 and 1882 a small collection of ichthyic remains was obtained by Dr. C. D. Walcott, Director of the United States Geological Survey, in the Kanab Valley, Utah, and adjoining regions in Arizona. These remains, which have recently been placed in the hands of the writer for investigation, are extremely fragmentary, and do not premit of accurate specific determinations. Of the few genera which are tolerably well indicated, such as *Pholidophorus* and several *Lepidotus*-like forms, it cannot be said that they evince anything in common with the Triassic fauna of the eastern States. Some resemblance is to be noted between the Kanab fish-fauna and that of Perledo, near Lake Como, but the general aspect of the material collected by Walcott is much more suggestive of Jurassic than of Triassic relations. This might very well happen notwithstanding the horizon be definitely proved by stratigraphic and other evidence to be of Triassic age, as other instances of pioneer faunas and overlapping types are not uncommon. It does not appear, however, that the data thus far obtained warrants more than a plausible supposition that the Kanab beds are of Triassic age, their reddish color and relative position being consistent with what we should expect of rocks of that horizon. Accepting the evidence furnished by the fossil fishes at its full value, we shall have to regard the red beds of Kanab Cañon as belonging presumably to the Lias.

[1] Evans, H. M., A. New Cestraciont Spine from the Lower Triassic of Idaho Bull. Dept. Geol. Univ. of California, vol. iii. (1904), pp. 397-402, pl. xlvii.

The Triassic Fishes of New Jersey.

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SUMMARY.

PRELIMINARY CONSIDERATIONS.

The character of the Triassic fish-fauna of the eastern United States from Virginia northward is singularly homogeneous and monotonous. All told, there are only half a dozen genera repre-

sented, four of which are known by a solitary species each. Of the remaining genera, *Catopterus* and *Semionotus,* the latter is numerically the more important, and is also represented by a larger number of species.

It is often difficult to distinguish the species of *Semionotus* from one another, except in the case of well preserved individuals, but the genera can always be separated with ease. The serration of the posterior scale-borders in *Catopterus,* and delicately fringed condition of the anterior ray of all the fins, are characters by which any member of this genus can be recognized at a glance. The fringed appearance of the fins just mentioned is due to the presence of numerous spine-like splints or raylets known as *fulcra,* which are peculiar to ganoid fishes—or those having rhomboidal, enameled scales. According to the familiar dictum of Johannes Müller, "every fish with fulcra on the anterior edges of one or more of its fins is a ganoid." The group of fishes embraced in this category was vastly more important during remote geological periods than in later times, and at the present day it is on the verge of extinction. In fact, not more than seven genera of the modern fauna can be classed as ganoids, according to the more precise definition of this series, the most familiar of these being the sturgeon (*Acipenser*), garpike (*Lepidosteus*), and bow-fin (*Amia*). Recent ganoids, with the exception of the sturgeon, have acquired a fresh-water habitat, whereas their predecessors were chiefly marine.

It is probable that the Triassic fishes we are about to consider belonged to a more or less brackish-water fauna, as there is abundant evidence to show that the shallow-water sediments of the Connecticut Valley Trias, and of the Newark series in New Jersey, were deposited under estuarine, or off-shore conditions. It need scarcely be remarked that of this exclusively ganoid fauna, all the genera are now extinct. One of them, *Diplurus,* belongs to the Crossopterygian or fringe-finned ganoids, of which there are but two living representatives—*Polypterus* and *Calamoichthys.* The remaining five belong to the group of Actinopterygian fishes, and one of the number, *Catopterus,* is interesting in that it stands close to the ancestral line of the sturgeons, which originated as far back as the Devonian.

As to the probable causes which brought about the destruction of the immense quantity of fish-life as is found in the Boonton and other localities, these can only be postulated in a general way, and have already been referred to in the preceding pages. It is evident that a vast number of creatures met their death suddenly, sank to the bottom and became embedded in sediment before their bodies had suffered serious injury, either from decomposition or mechanical disruption. Accidental lengthening or compression of the body, due to wave or current action, and such other deformation as occurred prior to the fossilization process, was no doubt accomplished quickly. It is even possible, in some cases, to determine the direction of current or wave action, since, if two individuals are found lying at right angles to each other on the same slab (as in Plate XIV), and one of them is vertically and the other longitudinally compressed, it is evident that such distortion must have been produced by a force operating in one and the same direction. Friction of the water on the bottom, and the wash of sediment by tidal action, offer convenient and plausible explanations of these appearances. The extent to which the original contour of fish skeletons has become distorted by accidents of fossilization, which seem to have been unusually prevalent at Boonton, cannot be fully appreciated except by those who have had considerable experience in collecting, or in the determination of species.

A variety of accidental phenomena has been suggested to account for the destruction of multitudes of brackish-water or marine organisms simultaneously in such manner as to produce what are known as "bone-beds" or "fish-beds." Amongst the more important of these may be mentioned: (1) Earthquake shocks; (2) volcanic explosions, with the emission of poisonous vapors; (3) sudden changes in temperature, or in salinity brought about by the shifting of currents, by irruptions from the outer sea into sheltered or brackish-water inlets, or by unusually copious discharges of fresh water into the open sea; (4) the accidental impounding of marine forms within land-locked embayments, including coral island lagoons, coal marshes, inundated areas, etc.; and (5) parasitic infections and other physiological disturbances. The possibility of some of these agencies

having led to the mortality of Eocene fishes found at Monte Bolcac in the Veronese was discussed by prominent Italian geologists more than a century ago.[1]

As to the correspondence between the Triassic fauna of eastern North America with organic assemblages of other regions, it must be admitted that the fishes alone furnish insufficient data for correlation. The vertebrate contingent of the Newark fauna is essentially a local one, and does not stand in close agreement with the corresponding element of the European or South African Mesozoic. On the other hand, we must not overlook the fact that a certain and not inconspicuous analogy exists between the Newark fish-fauna and that of the Alpine Trias, especially the Virglorian (Muschelkalk) of Perledo, near Lake Como, which contains a number of species of *Semionotus* closely resembling the American forms. In the Keuper of Besano both *Semionotus* and *Ptycholepis* occur, along with other forms having a Liassic aspect, and the association of these two genera in our local fauna immediately suggests that the Newark beds belong to the uppermost division of the Trias.

This conclusion with respect to the relations of the Newark system agrees with that shared by most palæobotanists who have investigated its flora, and whose opinions are brought together by I. C. Russell in his correlation paper on the Newark system.[2] The testimony furnished by palæobotany on this subject is held by most writers to be definite and reliable. According to L. F. Ward,[3] the most recent authority to discuss the relations of the Newark flora, the evidence of fossil plants fixes the horizon of the Newark "with almost absolute certainty at the summit of the Triassic system, and narrows the discussion down chiefly to the verbal question whether it shall be called Rhætic or Keuper.

[1] Gazola, G., Lettere recentemente pubblicate sui pesci fossili veronesi, con annotazioni inediti agli estratti delle medesime. Milan, 1793, and Verona, 1794.

[2] Russell, I. C., Correlation Papers: The Newark System (Bull. U. S. Geol. Surv. No. 85, pp. 126-131), 1892. Kümmel, H. B., The Newark System of New Jersey (Ann. Rept. State Geol. N. J. for 1897, pp. 23-159), 1898.

[3] Ward, L. F., The Plant-bearing Deposits of the American Trias (Bull. Geol. Soc. America, vol. iii, pp. 23-31), 1891. Principles and Methods of Geologic Correlation by means of Fossil Plants (Amer. Geol., vol. ix, pp. 34-47), 1891.

* * * The beds that seem to be most nearly identical, so far as the plants are concerned, are those of Lunz, in Austria, and of Neue Welt, in Switzerland. These have been placed by the best European geologists in the Upper Keuper. Our American Trias [Newark] can scarcely be lower than this, and it probably can not be higher than the Rhætic beds of Bavaria."

Newberry was mistaken in supposing that the fishes of the Newark system were not nearly related to those of any European formation,[1] but agreed with the majority of writers in the view that the evidence of fossil plants favored a correlation with the Uppermost Trias. Agassiz[2] at one time expressed an opinion that the fossil fishes of the Virginia area, and "from the so-called New Red Sandsone, indicate an age intermediate between the European New Red and the Oolite." Later he developed this view so far as to state that the fossils referred to correspond neither with the Triassic fishes of Southern Germany, nor with those from the English Lias, and he accordingly referred the Newark rocks to a group intermediate between the Trias and Lias, for which there is no European equivalent.[3]

Those desirous of tracing the correspondence between the Newark fish-fauna and various assemblages of the Alpine Trias may profitably consult the comparative lists given by Baron de Zigno of the species obtained from five well-known localities. In the following table we have arranged his list of the forms occurring at Perledo and that showing the principal American species in parallel columns. For a list of the localities from which fossil fishes have been obtained in greater or less abundance in the Newark system one may consult page 57 of the correlation paper of I. C. Russell, already referred to. A discussion will also be found in the same paper of the probable physical conditions under which the beds of the Newark system were deposited:

[1] Newberry, J. S., The fauna and flora of the Trias of New Jersey and the Connecticut Valley (Trans. N. Y. Acad. Sci., vol. vi, pp. 124-128), 1887.

[2] Agassiz, L., Proc. Amer. Assoc. Adv. Sci., vol. iv (1850), p. 276.

[3] *Idem,* Proc. Amer. Acad., vol. iii (1852-57), p. 69.

List of Fossil Fishes occurring in the Alpine Muschelkalk at Perledo.

1. *Lepidotus serratus* Bell.
2. " *pectoralis* Bell.
3. *Allolepidotus rueppelli* (Bell.).
4. " *nothosomoides* Deecke.
5. *Semionotus brevis* Bell.
6. " *balsami* Bell.
7. " *inermis* Bell.
8. " *dubius* Bell.
9. " *altolepis* Deecke.
10. " *bellotti* Rüppel.
11. " *trotti* Bell.
12. " *hermesii Bell.* (MS.).
13. " *lepisurus Bell.* (MS.).
14. *Archæosemionotus connectens* Deecke.
15. *Pholidophorus rueppelii* Bell.
16. " *oblongus* Bell.
17. " *lepturus* Bell.
18. " *porroi* Bell.
19. " *curioni* Bell.
20. *Urolepis macroptera* Bell.
21. " *microlepidotus* Bell.
22. " *elongata* Bell.
23. *Heptanema paradoxum* Rüppel.
24. *Belenorhynchus macrocephalus* Deecke.

List of Fossil Fishes occurring in the Newark Series.

1. *Semionotus ovatus* (W. C. Redfield).
2. " *robustus* (Newb.).
3. " *agassizii* (W. C. Redfield).
4. " *gigas* (Newb.).
5. " *fultus* (Ag.).
6. " *tenuiceps* (Ag.).
7. " *micropterus* (Newb.).
8. " *lineatus* (Newb.).
9. " *elegans* (Newb.).
10. " *brauni* (Newb.).
11. *Acentrophorus chicopensis* Newb.
12. *Catopterus gracilis* J. H. Redfield.
13. " *redfieldi* Egerton.
14. *Dictyopyge macrura* (W. C. Redfield).
15. *Ptycholepis marshi* Newb.
16. *Diplurus longicaudatus* Newb.

Systematic Descriptions.

Order ACTINOPTERYGII.[1]

Family SEMIONOTIDÆ.

Trunk more or less deeply fusiform, rarely cycloidal. Cranial and facial bones more or less robust, and opercular apparatus complete. Gape of mouth small, teeth styliform or tritoral. Notochord persistent, vertebræ not more than rings. Fin-rays robust, fulcra large, dorsal fin not extending more than one-half the length of the trunk. Scales rhombic, except occasionally in the caudal region.

[1] For sake of convenience, the two most important genera, *Semionotus* and *Catopterus*, are here treated slightly out of their usual order, the remaining genera, which are of excessively rare occurrence, being placed after them.

Genus Semionotus Agassiz.

Trunk fusiform. Marginal teeth slender, conical, somewhat spaced, inner teeth stouter; opercular apparatus well-developed, with a narrow arched preoperculum. Ribs ossified. Fulcra unusually large. Paired fins small, dorsal fin large, arising at or behind the middle of the back, and in part opposed to the relatively small anal; caudal fin slightly forked. Scales smooth or feebly ornamented, and the narrow overlapped margin produced at the angles and at the superior border. Flank-scales not more than twice as deep as broad, the dorsal ridge-series of acuminate scales forming a prominent crest.—(Woodward.)

The cranial osteology of this genus is imperfectly known, a consequence of the inferior preservation of most of the remains. Agassiz, in his great work on Fossil Fishes, described briefly the arrangement of cranial plates in *S. nilssoni,* and more recently E. Schellwien has furnished us with similar information regard-

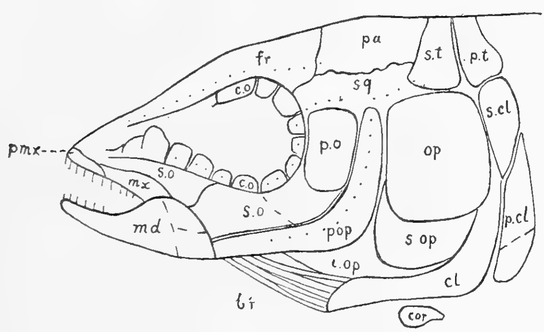

Fig. 9.

Semionotus capensis Woodw. Lateral aspect of head, $\times \frac{1}{1}$. *br,* branchiostegal rays; *cl,* clavicle; *co,* circumorbitals; *cor,* coracoid (?); *fr,* frontal; *i. op,* interoperculum; *md,* mandible; *mx,* maxilla; *pa,* parietal; *p. cl,* postclavicular scale; *p. o,* postorbital; *p. op,* preoperculum; *p. t,* post-temporal; *s. cl,* supraclavicle; *so,* suborbitals; *s. op,* suboperculum; *sq,* squamosal; *s. t,* supratemporal. Sensory canals are indicated by dotted lines; doubtful sutures by dashes (after Schellwien).

ing *S. capensis* (Fig. 9), both of these forms being trans-Atlantic species. Newberry remarks in his Monograph on Triassic Fishes that he has "not been able to verify by personal examination

the descriptions of the head plates of Semionotus given by European authors," but offered on his own part no new information as regards the head structure of American forms. Only within the past year has a really satisfactory figure of the head of an American species been published, and this, which we owe to Dr. G. F. Eaton, is unaccompanied by a textual description. In the following paragraphs it is not intended to present more than a general sketch of the cranial structure so far as it has yet been deciphered.

The membrane bones of the cranial roof form a continuous shield, extending from the snout nearly to the occipital border. The two principal pairs of bones are the narrow and elongate frontals, reaching from the premaxillaries to behind the orbits, and the much shorter parietals in contact with them posteriorly. As is frequently the case amongst the Semionotidæ, these pairs are not quite bilaterally symmetrical, but the sutures are more regular than in some other genera. Skirting the lateral border of the frontals, and extending also over the forward part of the parietals, are deep mucous canals, which are developed on the under side of the bones, and hence not commonly apparent from the external aspect. In *S. nilssoni* (Fig. 10), the impres-

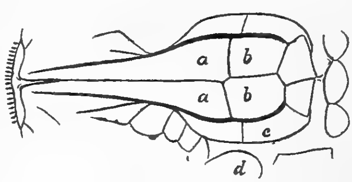

Fig. 10.

Semionotus nilssoni Ag. Dorsal aspect of head, slightly modified, after Agassi, $\times {}^1/_1$. *a,* frontals; *b,* parietals; *c,* squamosal; *d,* postorbital.

sions of these canals are unusually broad and deep, and so difficult to distinguish from sutures that Agassiz was misled into confusing them with the latter. For the benefit of those who may care to consult Agassiz's description of the latter head in this form, and seek acquaintance with a single perfectly preserved individual before attempting the decipherment of imperfect ones, we quote from Agassiz's original description as follows:

"Les fronteaux, *a, a,* sont fort allongés; leur prolongement antérieur ne se rétrécit pas très-considérablement; en sorte que la tête est moins effilée dans cette espèce que dans les autres. La suture qui les unit, est inégale, le frontal gauche étant plus large que le droit, et faisant saillie sur lui à sa partie postérieure. Les pariétaux, *b, b,* sont petits; le droit est cependant un peu plus grand que le gauche. Le mastoïden gauche, en partie conservé, *c,* montre à sa surface de très-petits tubercules pointus. L'orbite est assez petite; les sous-orbitaires qui l'entourent sont étroits et granuleux à leur surface. Les plaques buccales, *d,* considérablement plus larges, semblent complètement lisses, à en juger du moins par un fragment dont la surface est visible. L'opercule est beaucoup plus haut que large; les autres pièces operculaires sont enlevées." (*Poiss. Foss.* I, p. 230.)

Behind the parietals occur a pair of wedge-shaped plates corresponding to the supratemporals of Palæoniscus. These are followed in turn by the scaly post-temporals, which in most species have a decidedly Palæoniscus-like aspect. It is remarked by Schellwien, with regard to the plates forming the cranial roof, that "die Mittellinie, in welcher die paarigen Platten des Schädeldaches an einander stossen, ist keine gerade, sondern mehr oder weniger gewellte, anscheinend besonders stark in der Parietalregion. Die correspondierenden Platten sind auf beiden Seiten des Kopfes theilweise sowohl in der Grösse, wie in der Form verschieden ausgebildet."

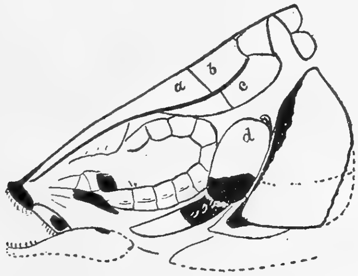

Fig. 11.

Semionotus nilssonni Ag. Lateral aspect of cranium, $\times 1/1$. Lettering as in Fig. 10.

The squamosal is a plate of variable width and irregular shape abutting against the parietals and frontals. It is terminated anteriorly by a ring of circumorbitals, but its posterior limits are apparently not the same for all species. The circumorbitals, as their name implies, are a series of small plates surrounding the orbit. They are of polygonal contour (Fig. 11), and are arranged much in the same manner as in Lepidotus, those along the lower border being of larger size and extending some dis-

tance in advance of the upper tier. Indications of a mucous canal are observable over part of the circumorbital ring in some species. Immediately beneath the latter is situated a series of suborbitals, which are much larger and less numerous than those of Lepidotus, Dapedius and related genera. Evidence of specialization is observable here, these large plates having no doubt resulted from the fusion of smaller ones. The boundaries between the suborbitals and contiguous plates have not been satisfactorily determined even in the best preserved individuals. The postorbital, or "plaque buccale" of Agassiz, is a large thin plate on either side of the head, situated between the circumorbitals and the operculum. It is sometimes in contact with the latter plate posteriorly, as in *S. bergeri* and possibly also in *S. nilssoni* (although it may have been displaced in the type so as to come to occupy this position accidentally), or in other cases it may be entirely separated from it by the preoperculum, as in *S. capensis*.

The opercular apparatus consists of (1) a large operculum, of variable shape, but generally with a narrower upper border; (2) a narrow, falciform preoperculum, with the mucous canal interrupted and appearing as a series of perforations; (3) a suboperculum, the exposed surface of which generally exhibits a sublunate outline; and (4) a triangular interoperculum. The posterior borders of the operculum and interoperculum are embraced by a large and heavy plate, often very conspicuous, the clavicle. This is similar to the preoperculum in form, but is much more solid, and its terminal angle in front is frequently thickened or otherwise prominent. It is succeeded behind by one or two enlarged postclavicular scales. There is a series of branchiostegal rays, but these, like the coracoid, are seldom well preserved, and hence not satisfactorily known. The dental characters have been indicated with sufficient fulness in the preceding family and generic diagnoses.

In the following systematic discussions, conscientious regard has been paid to the opinions of Professor Newberry, and none of the changes here introduced can be said to be inharmonious with his views, implied or expressed. But it is clear to everyone that this author, with all his clarity of perception, did not always

carry out his arguments to their logical conclusions, and, whether owing to conservatism or other reasons, he often declined taking a novel procedure, preferring to abide instead by precedent and established usage. In the second place, he was sometimes led through caution and hesitancy to doubt his own determinations, instances being not at all uncommon where he has contradicted himself in this respect.

As has been remarked by Dr. Eaton, "the late Professor Newberry belonged to a school of palæontologists whose practice it was to decide all doubtful cases in favor of a new species." Examples of this tendency are to be found in his recognizing a distinction between *S. fultus* and *S. macropterus,* species which had been previously united by J. H. Redfield. *Semionotus latus* was also regarded as a distinct species, although pronounced a synonym of *S. tenuiceps* by earlier writers, nor are these the only instances that might be cited. Even the identity of Egerton's genus "Ischypterus" with Semionotus was more than suspected by him, although he appears not to have arrived at a decided conviction on this point. Wherever the former generic term occurs in the present article, it is to be understood as a synonymy of Semionotus, this being the accepted usage. The new species of Semionotus described by Professor Newberry were named by him as follows:

Semionotus	*("Ischypterus")*	*gigas.*
"	"	*robustus.*
"	"	*micropterus.*
"	"	{ *lineatus.*
"	"	{ *alatus.*
"	"	{ *lenticularis.*
"	"	{ *modestus.*
"	"	{ *elegans.*
"	"	*minutus.*

Newberry took occasion to observe more than once in his Monograph that his work was liable to modification through the discovery of more and better material, and he predicted that further investigation would probably reduce instead of increase the number of species. The names bracketed together in the

above list are treated as synonyms, the legitimacy of which course was practically acknowledged by Newberry. For instance, in the description of his so-called *I. alatus,* he tells us that he "hesitated long before separating it from *I. lineatus,* as it is probable that the two will be found to run into each other, so that they must be regarded as varieties of one species." Similarly the differences between his *Ischypterus elegans* and *I. lenticularis* were admitted to be so slight as to be perhaps attributable to age or sex; and under his description of *I. modestus* we read: "The fishes most nearly allied to these are those which I have included under the name of *I. elegans,* and it is perhaps not certain that they should be regarded as distinct." It will be seen, therefore, that no violence is done to the views of the original author, to whom we owe much and valuable enlightenment, in introducing a few slight modifications.

Semionotus ovatus (W. C. Redfield).

(Plates 4-6.)

1842. *Palæoniscus ovatus,* W. C. Redfield, Amer. Journ. Sci., vol. xli, p. 26.
1847. (?) *Tetragonolepis,* Sir P. G. Egerton, Quart. Journ. Geol. Soc., vol. iii, p. 277.
1850. *Ischypterus ovatus,* Sir P. G. Egerton, *op. cit.,* vol. vi, p. 10.
1888. *Palæoniscus ovatus,* J. H. Redfield, Monogr. U. S. Geol. Surv., vol. xiv, p. 27.
1888. *Ischypterus ovatus, Ibid, loc. cit.*
1903. *Semionotus ovatus,* G. F. Eaton, Amer. Journ. Sci., [4] vol. xv, p. 266.

A large species, attaining a total length of about 23 cm. (9 in.), with trunk very much deepened midway between the head and dorsal fin. Scales large and thick, becoming gradually deepened toward the middle of the flanks; tail strong and considerably expanded. Number of dorsal and anal fin-fulcra greater than in any other species, each fin having sometimes as many as twenty or more. Length of the longest fulcrum of dorsal fin nearly equaling one-half that of the anterior margin of the fin.

In the original description of *S. ovatus,* by W. C. Redfield, it is stated that "it exceeds all the known American species in the comparative width or roundness of its form, and is also remarkable for the large size of its scales. It is of rare occurrence, and

owing probably to its great thickness, is seldom obtained in a perfect form." The younger Redfield, commenting on the same species in 1854, pronounced it "the broadest and most ovate species of Palæoniscus that is known," and added further that "in size of the scales it resembles *P. Agassizii,* but its form will readily distinguish it."

This species is recorded by both of the Redfields from the Connecticut Valley Trias and from Boonton, New Jersey. The same distribution is claimed for it by Newberry, who also identifies with this species a fragmentary individual from the Triassic Coalfield of Virginia, originally referred to Tetragonolepis by Sir Philip Grey Egerton. It is to be observed that all of the more perfect examples have been obtained from Boonton, and the recognition of this species from other localities depends upon the evidence of more or less fragmentary remains. The original of Newberry's published figure is now preserved in the American Museum of Natural History, in New York. In Plate VI. is represented what is evidently a young individual of this species, and it will be noticed that some resemblance exists between it and the published figure of the so-called *S. beardmorei.*

Semionotus robustus (Newberry).

1888. *Ischypterus robustus,* J. S. Newberry, Monogr. U. S. Geol. Surv, vol. xiv, p. 36, pl. vi., fig. 1.

A species of slightly smaller size than the preceding, and stated to be distinguished from it by "the great height, breadth and strength of the dorsal fin and its anterior position." Dorsal fin-fulcra very numerous, strong, curved; rays of dorsal fin 11, very strong. Pectorals relatively long and broad; pelvic fins inserted nearly opposite the anterior margin of the dorsal. Dorsal ridge-scales well developed, forming a prominent crest; trunk scales large and strong.

This species, of which only two or three examples are known, is doubtfully distinct from *S. ovatus.* During the time this report was in preparation Newberry's originals were packed in cases awaiting rearrangement in the American Museum of Natural History in New York, and hence not available for study. They were derived from Boonton, and no others have since been obtained.

Semionotus agassizii (W. C. Redfield).

(Plate I.; Plate II., Figs. 5, 9, 10, 12; Plate III., Figs. 1, 2; Plates VII., VIII.)

1841. *Palæoniscus agassizii,* W. C. Redfield, Amer. Journ. Sci., vol. xli., p. 26.
1850. *Ischypterus agassizii,* Sir P. G. Egerton, Quart. Journ. Geol. Soc., vol. vi., p. 10.
1856. *Ischypterus marshi,* W. C. Redfield, Proc. Amer. Assoc. Adv. Sci., pt. ii., p. 188 (name only).
1888. *Ischypterus agassizii,* J. S. Newberry, Monogr. U. S. Geol. Surv., vol. xiv., p. 30, pl. iii., Fig. 1.
1888. *Ischypterus marshi,* J. S. Newberry, *ibid.,* p. 28, pl. ii., Fig. 1.
1903. *Semionotus marshi,* G. F. Eaton, Amer. Journ. Sci. [4], vol. xv., p. 264, pl. v., Figs. 5, 9, 10, 12; pl. vi., Figs. 1, 2.

D. 9-10; C. 17; A. 9; P. 12.

A large and elegantly fusiform species, attaining a total length to the base of the caudal fin of about 25 cm., in which the length of the head and opercular apparatus is contained three and one-half times. The maximum depth occurs between the paired fins, where the number of longitudinal scale-rows is about 20. Number of transverse scale-rows, counting along the lateral line, about 34. Scales universally large and thick. The boat-shaped dorsal ridge-scale covering the base of the dorsal fin anteriorly is rather small, rounded in front and not notched behind, the posterior extremity prolonged instead into a fine point. Fins strong, but relatively short, the caudal rather prominently forked, and with about 17 rays. Dorsal, anal and pectoral fins with about 14 fulcra each, the ventral with about 12. Apparently four dorsal fin-fulcra originate on the dorsal line over the basal supports, the fifth being slightly less than one-half the length of the anterior fin-margin.

The original description of this species by W. C. Redfield is very meagre, the principal characters noted by him being the stoutness of the fins, and the usually disturbed condition of the dorsal ridge-scales. A more accurate definition was drawn up by John H. Redfield in the report presented by him to the American Association of Geologists and Naturalists in 1845, portions of which were published in the Proceedings of the Association for 1856, and still others by Professor Newberry, in 1888. Those to whom these sources are not readily accessible may find satisfaction

in having the original description placed before them, which we quote as follows:

"Head narrow and pointed, scales large and smooth, sometimes with faint concentric striæ; those of the anterior portion of the dorsal ridge very much elongated, strong and pointed, and apparently erectile; when in an erect position much resembling rays, and giving the appearance of a comb-like dorsal fin; back arched, but not so abruptly as in *P. tenuiceps.* The widest portion of the fish is found just anterior to the ventral fin; pectoral fin moderate; anterior raylets rather short; primary rays, six or eight; ventral fins small; anterior raylets, about ten; primary rays, about five or six; dorsal fin large, triangular, preceded by erect, pointed scales; anterior raylets very long, twelve or more in number; primary, eight to ten; anal fin large, but not so much elongated as in *P. tenuiceps* or *P. fultus;* anterior raylets very strong, about twelve in number; primary rays, six to eight; tail forked, lobes acute, anterior raylets rather stout, rays of lower lobe much stouter than those of upper; length, seven to eight inches; breadth, three to three and one-half inches. Occurs at Sunderland, Mass.; Westfield and Middlefield, Conn.; Pompton and Boonton, N. J."

The additional characters are mentioned by Newberry that the dorsal ridge-scales, which are usually depressed, are less strongly developed than in *S. tenuiceps*, and "the arch of the back does not show the hump which is so characteristic of that species; the fins are very strong; the fulcra of the dorsal and anal fins unusually broad and long, forming arches nearly half an inch wide at the base, curving gracefully backward to a point."

It is further stated by Newberry that fishes answering to the above description occur nowhere except at Boonton. As for the remarkably similar specimens from the Connecticut Valley, these were held by him to constitute a distinct species, which he described under the name of *Ischpterus marshi.* The latter form was supposed to differ from *S. agassizii* in having a less-deepened trunk, weaker dorsal and anal fins, and thicker scales arranged in more oblique rows along the flanks. At a subsequent period, although there is no published record of it in his writings, he appears to have become convinced that actual differences did not exist, and that *S. marshi* should be treated as a synonym of *S. agassizii.* This view certainly accords with all the facts, and is adopted in the present paper. But as Newberry did not himself propose the abandonment of his *S. marshi,* it is proper to explain this matter more fully.

There are preserved in the American Museum of Natural History in New York three very excellent specimens of Semionotus, from Sunderland, Mass., which were presented to that institution a number of years ago by Mr. Robert L. Stuart, and are referred to by Newberry in his Monograph under the caption of *Ischypterus marshi.* One of them he mentions as "an exceptionally perfect specimen about twelve inches long," this being probably the identical individual which is shown in Plate VII. of this report, and forms the basis of our restoration in Plate I. Another of the trio is represented in Plate VIII., this one having the pectoral fin and dorsal ridge-scales very well preserved. After the completion of his Monograph, these specimens were again examined by Professor Newberry, and according to the veteran curator, Professor Whitfield, were redetermined by him as belonging to *S. agassizii,* this name being thereupon inscribed upon the labels. These specimens, which may be regarded upon Newberry's authority as belonging undoubtedly to *S. agassizii,* have more recently been investigated by Dr. G. F. Eaton, of Yale University, and his opinion is that no differences are to be observed between them and the type of *S. marshi,* which is preserved in the Yale Museum. Dr. Eaton's view that the species is "probably common to Massachusetts, Connecticut and New Jersey" is in accord with the original statement of Redfield.

The illustration given in Plate III., fig. 1, for the use of which we are indebted to Dr. Eaton, shows the head of the type-specimen of the so-called *S. marshi,* which is poorly represented in Newberry's figure. The tail, too, in the same illustration, has been largely restored without the fact being so indicated. Certain detached scales from different parts of the body are likewise reproduced from Dr. Eaton's article in the *American Journal of Science.* Plate I. of the present report having been drawn from an actual photograph, it has been thought advisable to leave the squamation, including the dorsal ridge-scales, and also the finrays, exactly as they occur in the original specimen, without attempting a restoration.

Semionotus gigas (Newberry).

1888. *Ischypterus gigas,* J. S. Newberry, Trans. N. Y. Acad. Sci., vol. vi., p. 127 (name only).
1888. *Ischypterus gigas,* J. S. Newberry, Monogr. U. S. Geol. Surv., vol. xiv., p. 49, pl. xiv., Fig. 3.

This species is founded upon the fragmentary caudal portion of a large example of Semionotus from the Newark series at Boonton, the total length of the fish being estimated by Newberry to have been about two feet. It is quite possible that the type specimen was simply a large-sized individual of *S. agassizii,* but in the absence of all other material the name may be allowed to stand in a provisional sense as indicating a form not clearly distinguishable from the preceding.

Semionotus fultus (Agassiz).

(Plate II., Figs. 1-4; Plate IX.)

1833-36. *Palæoniscus fultus,* L. Agassiz, Poiss. Foss., vol. ii., pt. i., pp. 4, 43, pl. viii., Figs. 4, 5.
1841. *Palæoniscus fultus,* W. C. Redfield, Amer. Journ. Sci., vol. xli., p. 25.
1841. *Palæoniscus macropterus,* W. C. Redfield, *ibid.,* p. 25.
1847. *Ischypterus fultus,* Sir P. Egerton, Quart. Journ. Geol. Soc., vol. iii., p. 277.
1850. *Ischypterus fultus,* Sir P. Egerton, *ibid.,* vol. vi., pp. 8, 10.
1877. *Ischypterus fultus,* R. H. Traquair, *ibid.,* vol. xxxiii., p. 559.
1888. *Ischypterus fultus,* J. S. Newberry, Monogr. U. S. Geol. Surv., vol. xiv., p. 34, pl. vi., Fig. 2; pl. vii., Fig. 1.
1888. *Ischypterus macropterus,* J. S. Newberry, *ibid.,* p. 41, pl. xii., Fig. 1.
1901. *Semionotus tenuiceps,* W. H. Hobbs, 21st Ann. Rept. U. S. Geol. Surv., pt. iii., p. 56, pl. iii., Fig. A *(errore).*[1]
1901. *Semionotus fultus,* E. Schellwien, Phys.-ökon. Gesellsch. Königsberg, p. 29, pl. iii., Figs. 4 (?), 5.
1903. *Semionotus fultus,* G. F. Eaton, Amer. Journ. Sci. [4], vol. xv., p. 261, pl. v., Figs. 1-4.
1895. *Semionotus fultus,* A. S. Woodward, Cat. Foss. Fishes Brit Mus., pt. iii., p. 58.

The synonymy given above is that generally concurred in by recent writers. The two species, *S. fultus* and *S. macropterus,*

[1] The present writer is not responsible for this determination. The original of Fig. *B* was referred by him to *S. fultus,* that of Fig. *A* to Catopterus.

were first united by J. H. Redfield in his report presented to the American Association of Geologists and Naturalists in 1845, but were again separated by Professor Newberry on the ground of their seeming to present slight differences in the proportions of length and depth—appearances due to varying conditions of preservaton. The principal characters distinctive of this species may be enumerated as follows:

D. 10; C. 15; A. 10; P. 10.

A gracefully fusiform species attaining a total length to the base of the caudal fin of about 15 cm., in which the length of the head and opercular apparatus is contained three and one-half times. The maximum depth of trunk, which is equal to about one-fourth the total length, occurs midway between the head and dorsal fin, where there are about 20 longitudinal rows of scales. Lateral line scales about 33. Dorsal fin arising at mid-length, pelvic nearer to anal than to the pectoral pair, arising opposite a point directly in advance of the dorsal. Caudal not much forked. Anal with 10 rays, partly opposed to hinder half of the dorsal, its origin being on the third oblique scale-row in advance of the dorsal fin. Dorsal fin-fulcra about 12, anal 10, ventral and pectoral 10 each. Apparently four dorsal fin-fulcra originate on the dorsal margin over the interneurals. The fifth dorsal fulcrum has its origin adjacent to that of the first ray (Fig. 12), and is about equal in length to one-half the anterior margin of the fin. Scales smooth and not serrated posteriorly, the deepest ones occurring in the fourth row behind the clavicular arch; these are about twice as deep as they are wide in their exposed portion. Dorsal ridge-scales acuminate.

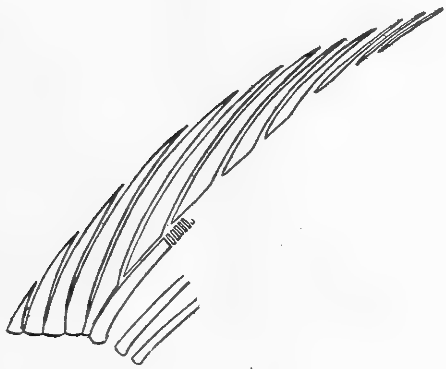

Fig. 12.
Semionotus fultus Ag. Fulcra and anterior rays of dorsal fin.

As already remarked, the sole criterion relied upon by Newberry for distinguishing the so-called *S. macropterus* consisted in a supposed relatively greater depth of body—"the fusiform and slender fish standing for *I. fultus,* and the broader one for *I. macropterus.*" Curiously enough, it has been shown by Dr. Eaton, after a study of Newberry's originals in the American Museum of Natural History, that whereas one of the specimens of *S. macropterus* in its compressed and flattened condition is deeper than a type of *S. fultus,* all the others are proportionately more slender.[1] J. H. Redfield, after advocating the suppression of the name *"macropterus,"* remarks that *S. fultus* is specially characterized by the length of the dorsal and anal fins, which are even longer than in *S. tenuiceps.* [2] A comparison of text Figures 12 and 13 will enable one to appreciate the differences as regards structure of the dorsal fin in this species and *S. micropterus.* In Plate IX. of this report is given a photographic reproduction of one of Newberry's originals.

This is the most abundant of all the New Jersey species, and in the Connecticut Valley Trias is only inferior numerically to the ubiquitous *S. tenuiceps.* The average length is stated by New-

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[1] Amer. Journ. Sci. [4], vol. xv., p. 262.

[2] *Cit.,* Newberry, Monogr. U. S. Geol. Surv., vol. xiv. (1888), p. 35.

berry to be about six inches, the extreme of eight inches being only rarely attained.

Semionotus tenuiceps (Agassiz).

1835-36. *Eurynotus tenuiceps,* L. Agassiz, Poiss. Foss., vol. ii., pt. i., pp. 159, 303, pl. xiv. c, Figs. 4, 5.
1837. *Palæoniscus latus,* J. H. Redfield, Ann. Lyceum Nat. Hist., N. Y., vol. iv., p. 38, pl. ii.
1837. *Eurynotus tenuiceps,* J. H. Redfield, *ibid.,* p. 39.
1841. *Eurynotus tenuiceps,* E. Hitchcock, Geol. Mass., vol. ii., p. 459, pl. xxix., Figs. 1, 2.
1841. *Palæoniscus latus,* W. C. Redfield, Amer. Journ. Sci., vol. xli., p. 25.
1850. *Ischypterus latus,* Sir P. Egerton, Quart. Journ. Geol. Soc., vol. vi., p. 10.
1857. *Eurinotus ceratocephalus,* E. Emmons, Amer. Geology, pt. 6, p. 144, pl. ix *a.*
1860. *Eurinotus ceratocephalus,* E. Emmons, Manual Geology, ed. 2, p. 188, Fig. 164.
1877. *Ischypterus latus,* R. H. Traquair, Quart. Journ. Geol. Soc., vol. xxxiii., p. 559.
1888. *Ischypterus tenuiceps,* J. S. Newberry, Monogr. U. S. Geol. Surv., vol. xiv., p. 32, pl. v., Figs. 1-3; pl. vii., Fig. 3.
1888. *Ischypterus latus,* J. S. Newberry, *ibid.,* p. 46, pl. liii., Fig. 3.
1889. *Allolepidotus americanus,* W. Deecke, Palæontogr., vol. xxxv., p. 114.
1895. *Semionotus tenuiceps,* A. S. Woodward, Cat. Foss. Fishes Brit. Mus., pt. iii., p. 59.
1901. *Semionotus tenuiceps,* W. H. Hobbs, 21st Rept. U. S. Geol. Surv., pt. iii., p. 56 *(non* pl. 4).
1903. *Semionotus tenuiceps,* G. F. Eaton, Amer. Journ. Sci. [4], vol. xv., p. 295.

A species attaining a total length of about 20 cm., and readily distinguished from all others (except in young stages) by the excessive development of the dorsal ridge-scales; these are very large and conspicuous, and, in mature individuals, comparatively obtuse. The anterior dorsal outline is considerably arched, usually forming a characteristic "hump" immediately behind the head. Length of head and opercular apparatus less than the maximum depth of the trunk, and contained four times in the total length of the fish. Fins as in *S. fultus.* Scales smooth and serrated, those of the middle of the flank in part twice as deep as broad. The dorsal ridge-scale immediately in advance of the dorsal fin has its posterior border obtuse, and not produced, and the corresponding ridge-scale in front of the anal fin

is notched behind. Ribs more strongly developed than in any other species.

It is usually possible to determine this form with great facility, even in the case of fragmentary remains, none of the other species having the back so much elevated immediately behind the head, and set along the middle with such long, thickened, distally pointed or clavate scales. The ribs are also more conspicuous than in most other species, their curved outlines showing sometimes even when covered with scales. Owing to the frequency with which this species has been illustrated, and impossibility of mistaking it amongst collections, it has not been considered necessary to figure it in the present report.

S. tenuiceps outnumbers all other species in the Connecticut Valley Trias, and is tolerably abundant also in New Jersey. At Turner's Falls and at Sunderland, Mass., it is especially common, probably more than one-half of the individuals derived from the latter locality pertaining to this form.

Semionotus micropterus (Newberry).

(Plate II., Figs. 6-8, 11, 13.)

1888. *Ischypterus micropterus,* J. S. Newberry, Trans. N. Y. Acad Sci., vol. vi., p. 127 (name only).
1888. *Ischypterus micropterus,* J. S. Newberry, Monogr. U. S. Geol. Surv., vol. xiv., p. 31, pl. iv., Figs. 1, 2; pl. xii., Fig. 2.
1893. *Ischypterus newberryi,* S. W. Loper, Pop. Sci. News, p.
1903. *Semionotus micropterus,* G. F. Eaton, Amer. Journ. Sci. [4], vol. xv., p. 263, pl. v., Figs. 6-8.

D. 8; C. 15; A. 8.

A regularly fusiform species attaining a total length to the base of caudal fin of about 20 cm., the maximum depth occurring in the pectoral region and not exceeding 8 cm. The dorsal and ventral contours are more strongly convex than in *S. fultus,* but the relative position and size of the fins are about the same in the two species. Dorsal, anal and pectoral fin-fulcra relatively shorter than in *S. fultus.* Apparently three dorsal fin-fulcra originate on the dorsal line over the interneurals. The fifth dorsal fulcrum has its origin on the anterior margin of the an-

terior ray at a considerable distance from its base, and is about one-third as long as the anterior fin-margin (Fig. 13). Pec-

Fig. 13.

Semionotus micropterus (Newb.). Fulcra and anterior rays of dorsal fin.

torals with upwards of 20 fulcra. Ridge-scales moderate, spiniform, the one immediately in advance of the dorsal fin slightly produced into a point behind. Scales frequently serrated, those below the lateral line on the flanks tending to become bi- or tridentate on the postero-inferior angle (text-fig. 13).

According to Newberry, the most striking diagnostic characters of this species are "its pointed rostrate, depressed muzzle; conical narrow head, horizontal below; the wedge-shaped outline of the body, which is widest near the head; the small and delicate fins, and the narrow and oblique tail." The maximum size attained by this species, as stated by the same authority, is "ten and one-half inches long by three and one-half inches wide, the smallest * * * only about three and one-half inches long." The fin and scale characters have been worked out in detail by Dr. G. F. Eaton, from whose paper the illustrations given in Plate II. are borrowed.

This species is known only from Connecticut, and is stated by Newberry to be especially common in the vicinity of Durham. It is possible that the detached head figured by Schellwien, in Plate III., fig. 4, of his memoir belongs to the species in question, this being one of the few in which the cheek plates are granulated.

Semionotus lineatus (Newberry).

(Plates X., XI.)

1888. *Ischypterus lineatus,* J. S. Newberry, Trans. N. Y. Acad. Sci., vol. vi., p. 127 (name only).
1888. *Ischypterus alatus,* J. S. Newberry, *ibid.,* p. 127 (name only).
1888. *Ischypterus alatus,* J. S. Newberry, Monogr. U. S. Geol. Surv., vol. xiv., p. 37, pl. viii., Figs. 1, 2.
1888. *Ischypterus lineatus,* J. S. Newberry, *ibid.,* p. 40, pl. xi., Figs. 1, 2.

The original description of this species is as follows:

"Fishes six to eight inches in length; outline, when perfectly preserved, uniformly arched above and below; head relatively large, contained about four times in the entire length, broadly conical in outline; fins all large; fulcra arched; scales of dorsal line spinous and strong, but less developed than in *I. tenuiceps;* ribs and interspinous bones frequently preserved; scales on sides thick and strong, arranged in continuous rows from the head backward, so as to give a lined appearance, which has suggested the specific name."

It will be observed that the above diagnosis applies to robust and comparatively large-sized fishes, with thick scales and strong fins and ribs. Distinctive characters, by which the species can be readily separated from others accompanying it in the same formation, are not embraced in this general definition. For instance, nothing is stated in regard to the fulcra, except that they are "arched"; their number, and likewise that of the fin-rays, is not given in the text, nor is it apparent from the figures, and it is evident that one of the latter has been more or less restored. In a word, the species has not yet been adequately defined, and on inquiring in what light Newberry viewed its relations to other species, we find that he was considerably perplexed over their distinction. In one place, for instance, it is stated by him [1] that "the fishes of this group [referring to *S. lineatus*] are not easily separated from some of their associates, some individuals resembling those of *I. lenticularis;* but in these latter the outline is more symmetrical, the fins smaller, the scales more delicate, par-

[1] Monogr. U. S. Geol. Surv., vol. xiv. (1889), p. 40.

ticularly those of the dorsal line. On the other hand they approach through the smaller individuals the group to which I have given the name of *I. elegans;* but these latter are smaller, the arch of the back is higher, the head more depressed and acute, the fins and scales are more delicate. Still another variety, including the narrower forms, comes nearer to *I. fultus.* On the whole, however, this group of long, ovoid fishes, from two to three inches wide, are distinguishable at a glance from those which have the narrow lanceolate outlines of *I. fultus.*"

At the close of his general remarks on the genus Ischypterus, on page 27 of his Monograph, Newberry makes the following significant statement: "In the following pages, so far as I have been able, I have enumerated and defined all the species of the genus which have come under my observation. I deem it necessary to say, however, that future observations will probably diminish rather than increase the number of forms in which the differences should be given specific value. For example, *I. alatus* may prove to be only a variety of *I. lineatus,* and *I. modestus* a phase of *I. elegans;* but with marked differences and without connecting links, so far as yet observed, it has seemed to me hardly justifiable without further evidence of identity to unite them under a common name."

Amongst the species admitted by Newberry to bear a close resemblance to *S. lineatus,* his so-called *S. alatus* approaches it so closely as to have created doubt in the author's mind whether it was really distinct from the form under consideration. His remarks on this subject are as follows: "The fishes to which I have given the name of *Ischypterus alatus,* and have represented in Pl. VIII., are perhaps most like those under consideration [*S. lineatus*], and I have hesitated long before separating them; indeed it is probable they will be found to run into each other, so that they must be regarded as varieties of one species." Not only was their founder sceptical as to a distinction between *S. lineatus* and *S. alatus,* but no one else who has examined his types has been able to discover essential differences between them. They are here regarded as identical, and it may be further stated that the resemblance between *S. lineatus* and *S. elegans* is such as to excite suspicion lest we have not to do in the one case with

the adult, and in the other with immature forms belonging to one and the same species.

Little can be added to the definition already given of *S. lineatus,* for the reason that no further satisfactory material has come to light. In determining fragmentary individuals, the chief features to be relied upon are first of all the dorsal and anal fin-fulcra, which form a fringe fully as wide at the base as in *S. ovatus,* are as strongly curved as in that species, and are relatively longer. The moderately deep trunk, conspicuous ribs, and minor scale characters are also of service in distinguishing these fishes from other members of the same fauna.

Semionotus elegans (Newberry).

(Plate XII.)

1888. *Ischypterus elegans, modestus, lenticularis,* J. S. Newberry, Trans. N. Y. Acad. Sci., vol. vi., p. 127 (names only).
1888. *Ischypterus elegans,* J. S. Newberry, Monogr. U. S. Geol, Surv., vol. xiv., p. 37, pl. vii., Fig. 2; pl. x., Fig. 1; xiv., Figs. 1,2.
1888. *Ischypterus modestus,* J. S. Newberry, *ibid,* p. 38, pl. ix., Figs. 1-3.
1888. *Ischypterus lenticularis,* J. S. Newberry, *ibid,* p. 39, pl. x., Figs. 2, 3.

D. 11; C. 15; A. 7. Lat. line scales about 32 *(fide* Newberry).

A species of slightly smaller size than the preceding, and distinguished from it only by its fin and scale characters. Dorsal fin arising at mid-length, with 12 fulcra, which are shorter and more closely appressed than in *S. lineatus.* Anal fin not extending to the base of the tail, with about 10 fulcra. Squamation regular, firmly united, and hence usually preserved intact; number of scales along the lateral line about 32, in transverse rows at widest part of trunk about 20; ridge-scales in advance of the dorsal fin 18-20, moderate in size; the hindermost ridge-scale shield-shaped, not emarginate posteriorly. Dorsal and ventral outlines symmetrically arched, but rapidly contracting behind the median fins to a depth equal only to about half that of the middle of the trunk.

It will be noticed in the above synonymy that three of Newberry's species are united under one head. The propriety of this arrangement is self-evident, there being absolutely no characters

for distinguishing them from one another. This was virtually acknowledged by Newberry, as the following extracts show, although through hesitancy he maintained their formal separation. Under the description of *S. elegans* we read:

"This is the neatest species of the genus known to me; the curves of the outline of the body are graceful, the scaling crowded but exact. In form it most nearly resembles *I. lineatus*, but is smaller and broader, the back more distinctly and regularly arched, and the scales more numerous." As to the affinities of the so-called *S. modestus*, Newberry remarks: "The fishes most nearly allied to these are those which I have included under the name of *I. elegans*, and it is perhaps not certain they should be regarded as distinct," and finally, under the head of *"Ischypterus lenticularis,"* it is stated: "The relation between these smaller ovoid fishes is rather to those to which I have given the name *I. elegans*, and here the differences may be those of age or sex. The group designated by the latter name consists of fishes which are much smaller, often not much more than half the length and breadth, the lower line of the body being nearly straight, the upper highly arched before the dorsal fin, concavely narrowed behind. Hence I have supposed that they constitute a distinct species."

There is still further proof of Newberry's indecision in this matter. Examination of the co-types of his so-called *S. modestus*, now preserved in the American Museum of Natural History in New York, shows one of them to bear an original label in Newberry's handwriting, which reads as follows: *"Isch. modestus*.—Perhaps only a variety of *Isch. elegans* N., but having a broader and more rounded head, stronger fins, and larger and thicker scales.—J. S. N." The scant importance of these characters can be appreciated on comparing the figure of this specimen, which is given at the bottom of his Plate IX, with the figures properly referred to *S. elegans*.

Anyone who attentively examines a large series of Boonton fishes, and attempts to identify the more slender and elegantly fusiform species according to Newberry's ideas, will appreciate the difficulties presented by the wide range of effects produced by distortion, faulty preservation, and individual variation. The

contour of the head, curvature of the dorsal and ventral margins (within certain limits), and slight differences in the thickness and obliquity of the squamation, will come to be regarded as characters of minimum importance; and in the present instance, absolutely valueless for discriminating between *S. elegans, S. modestus* and *S. lenticularis.* In Plate XII we have refigured one of Professor Newberry's originals.

Semionotus brauni (Newberry).

1886. *Palæoniscus latus,* L. P. Gratacap, Amer. Nat., vol. xx., p. 243, text-fig. (*errore*).
1888. *Ischypterus brauni,* J. S. Newberry, Trans. N. Y. Acad. Sci., vol. vi., p. 127 (name only).
1888. *Ischypterus brauni,* J. S. Newberry, Monogr. U. S. Geol. Surv., vol. xvi., p. 43, pl. xii., Fig. 3, pl. xiii., Figs. 1, 2.

A small species, attaining a total length to the base of caudal fin of about 10 cm., in which the length of the head and opercular apparatus is contained in a little more than three times. Cranial bones granulated. Fins small, with delicate fulcra and rays; dorsal and anal remote, the latter extending to the base of the caudal. Scales rhomboidal or quadrangular, remarkably uniform in size over the greater part of the trunk. Dorsal ridge-scales small, anteriorly rounded, and terminating in a short, pointed prolongation behind.

This small and imperfectly known species occurs at a horizon several thousand feet lower than that of Boonton, being limited to the base of the Triassic system in New Jersey. The particulars of its occurrence are thus indicated by Newberry: "The only locality from which fishes of the present species have been obtained is Weehawken, N. J. Here, beneath the trap of the Palisades, is a stratum of highly metamorphosed slate which was once a bituminous shale, but which has been baked by the effusion of the great mass of molten matter above it; the fishes are found in this slate. In some layers it also contains great numbers of bivalve crustaceans (*Estheria*), which would seem to indicate that it was deposited in brackish water."

DOUBTFUL SPECIES.

A number of small forms, some of them no doubt representing the young of different species, have been described from the Connecticut Valley and from New Jersey, but owing to one cause or another, such as faulty preservation, inadequate description, or subsequent injury to or loss of the type-specimens, the names which have been proposed for them cannot be said to rest upon a secure foundation. In this category may be placed the so-called *"Ischypterus parvus"* founded upon a figure published in Hitchcock's *Geology of Massachusetts* in 1835; *"Ischypterus minutus"* Newberry, from Durham, Connecticut; *"Ischypterus newberryi"* Loper, also from Durham; and *"Ischypterus beardmorei"* Smith, from Boonton. The last name was proposed without definition for a specimen figured in the *Metropolitan Magazine* for October, 1900 (p. 502). Except for its small size, the original (which belongs to Mr. G. C. Berrien, of Upper Montclair) is suggestive of *Semionotus ovatus.* Mr. Loper's species is considered by Dr. Eaton to be identical with *S. micropterus.*

Genus ACENTROPHUS Traquair.

Trunk fusiform; teeth slender. Fins small, with very large fulcra; dorsal fin short, opposed to the space between the anal and the pelvic pair; caudal fin symmetrical, slightly forked. Scales rhombic, smooth or feebly ornamented; no enlarged dorsal ridge-scales; the scales of the flank not much deeper than broad, and those of the ventral aspect nearly equilateral.

It will be noticed that the only trenchant distinction between this genus and Semionotus consists in the absence of enlarged ridge-scales.

Acentrophorus chicopensis Newberry.

1888. *Acentrophorus chicopensis,* J. S. Newberry, Monogr. U. S. Geol. Surv., vol. xiv., p. 69, pl. xix., Figs. 3, 4.

Under this name are described certain fishes of moderate size ("six inches long by one and one-half inches wide," according

to Newberry), which are too imperfectly preserved for satisfactory determination or definition. They have been obtained from but a single locality, in rather coarse sandy shales near Chicopee Falls, Mass., which have been considerably metamorphosed by igneous agencies. This circumstance, as stated by Newberry, "has obscured some of the details of structure, such as the surface of the scales, the shape and markings of the head-bones, etc., but has left the outlines of the body and the position and form of the fins distinctly visible. The most striking characters of these fishes are the narrow wedge-shaped form of body, the straightness of the dorsal and ventral lines, the smallness of the fins, the posterior position of the dorsal, and the rounded and unarmed margins of the median dorsal scales." Assuming the correctness of the generic determination, this is the only species of Acentrophorus which has yet been recognized in this country.

Family CATOPTERIDÆ.

Genus CATOPTERUS Redfield (*Redfieldius* Hay).

Trunk elegantly fusiform, head relatively small, tail hemiheterocercal. External bones more or less ornamented with ridges and tubercles of ganoine; no median series of cranial roof bones. Fins of moderate size, consisting of robust rays, more or less enameled, and distally bifurcated; fulcra well developed, short and closely set. Dorsal and anal fins triangular, the origin of the former behind that of the latter; caudal fin forked. Scales large or of moderate size, nearly or quite smooth, and serrated along their postero-inferior margin; dorsal ridge-scales not much enlarged. Teeth numerous, small, acutely conical.

This is an exclusively American genus, although a closely allied form, Dictyopyge, occurs in both Europe and America. These two genera constitute a family by themselves, *Catopteridæ,* which is evidently descended from the ancient *Palæoniscidæ,* the group from which modern sturgeons and paddle-fishes are also derived. The structure of the head and shoulder-girdle has not yet been worked out for these two Triassic genera, but they

have a general Palæoniscid aspect, the eye being far forwards, snout prominent, and gape of the mouth wide. In this short-lived family, also, specialization had not advanced so far as to result in the correlation of the dermal rays of the unpaired fins with their endoskeletal supports, and the scales are all rhombic and ganoid, as in the more ancient types.

Remains of Catopterus are on the whole less abundant than those of the accompanying genus Semionotus, both in New England and New Jersey, and as a rule are less perfectly preserved. Nevertheless, the characters presented by the former genus are so well marked and distinctive that there is seldom any difficulty in determining even the most fragmentary individuals. The most obvious peculiarity of the genus consists, as the name implies, in the remote position of the dorsal fin. In Semionotus the dorsal is always anterior to the anal, in Catopterus it is either opposite or posterior. The margins of all the fins are thickly set with fine fulcra, and present in consequence a delicately fringed appearance, and the fin-rays themselves are very numerous, finely articulated, and enameled. Other noticeable differences consist in the ornamented condition of the cranial bones, and serration of the hinder margin of the scales.

Although the genus Semionotus is represented in this country by half a dozen or more species, only two of Catopterus can be definitely recognized. These are *C. gracilis* Redfield and *C. redfieldi* Egerton, both founded on large and nearly complete fishes which differ from one another chiefly in the proportions of body proportions and scale characters. The so-called *C. parvulus* Redfield is probably to be regarded as the young of *C. gracilis*. *Catopterus minor* and *C. ornatus* Newberry are supposed to stand in a similar relation to *C. redfieldi*.

Catopterus gracilis J. H. Redfield.

(Plate XIII.)

1837. *Catopterus gracillis,* J. H. Redfield, Ann. Lyceum Nat. Hist., N. Y., vol. vol. iv., pp. 37-39, pl. i.
1841. *Catopterus gracilis,* W. C. Redfield, Amer. Journ. Sci., vol. xli., p. 27.
1888. *Catopterus gracilis,* J. S. Newberry, Monogr. U. S. Geol. Surv., vol. xiv., p. 55, pl. xvi., Figs. 1-3.

1895. *Catopterus gracilis,* A. S. Woodward, Cat. Foss. Fishes Brit. Mus., pt. iii., p. 2.
1901. *Semionotus fultus,* W. H. Hobbs, 21st Ann. Rept. U. S. Geol. Surv., pt. iii., p 56, pl. 4, Fig. *B* (*errore*).

The type species, attaining a total length of about 25 cm. Length of head with opercular apparatus about equal to the maximum depth of trunk, and contained five times in the total length of the fish; depth of caudal pedicle somewhat less than one-half that of the abdominal region. Cranial bones finely granulated. Pelvic fins arising about midway between the pectorals and anal; dorsal and anal fins subequal in size, and almost completely opposed. Scales smooth, none deeper than broad, those of the flank in the abdominal region very finely serrated.

The fin-formula for this species as given in the original description by J. H. Redfield is as follows:

D. 10-12; C. 30-40; A. 20-30; V. *circa* 8; P. 10-12.

In the additional notes on this form given by the elder Redfield, it is stated that "the pectoral fins are of an elongated form, and are strengthened on the anterior margin by one or two large and partly flattened rays, to the front of which the fringe of fine raylets [fulcra] is attached. Owing to this peculiarity of structure, the smallest section of the pectoral fin will often serve to identify this species."

Ordinarily there is little question as to what constitutes the type of a species. In the present instance, the original description is founded upon characters exhibited by four or five typical specimens, one of which is figured in Plate I. of Redfield's paper. This last specimen was stated to be in the possession of the Yale Natural History Society at New Haven, and is now preserved in the Peabody Museum of Yale University. The present whereabouts of the remaining co-types are unknown, hence the figured specimen at Yale is the only authentic example now in evidence that has served for the establishment of this species. Professor Newberry, who examined it during the preparation of his Monograph, concluded that it possessed a greater depth of trunk than is normal for this species, and proposed its transfer to *C. redfieldi,* Egerton. This procedure could only be justified in case

it were shown that the example in question displayed characters irreconcilable with the definition of *C. gracilis,* or differed beyond the limits of individual variation from the other typical specimens referred to in the original description. But neither of these requisite conditions has been fulfilled, nor apparently can they be, hence we may continue to regard Redfield's figured specimen as one of the authentic co-types of this species. It is to be hoped that its characters may be critically re-investigated, and in particular the details of its cranial osteology made known, since in this specimen the head-structure is unusually well displayed. It is observed by Newberry that "unfortunately the head bones are not only generally displaced, but they are covered with a coating which obscures the sutures, the matrix clinging to the granulated surfaces of the head bones much more closely than to the polished scales."

This species occurs at Boonton and at various New England localities, being especially abundant at Durham. The Connecticut Valley material is as a rule better preserved than that of New Jersey.

Catopterus redfieldi Egerton.

1847. *Catopterus redfieldi,* Sir P. Egerton, Quart. Journ. Geol. Soc., vol. iii., p. 278.

1888. *Catopterus redfieldi,* J. S. Newberry, Monogr. U. S. Geol. Surv., vol. xiv., p. 53, pl. xv., Figs. 1-3.

1895. *Catopterus redfieldi,* A. S. Woodward, Cat. Foss. Fishes Brit. Museum, pt. iii., p. 3.

"A broader species than the preceding [*C. gracilis*], and with scales not so long in proportion to their depth."—Egerton.

The above definition has been supplemented by a number of diagnostic characters pointed out by Newberry, and incorporated by him into a precise description, which has been condensed by Smith Woodward as follows:

"A comparatively robust species as large as the type. Length of head with opercular apparatus not more than two-thirds as great as the maximum depth of the trunk, and contained nearly six times in the total length of the fish; depth of caudal pedicle

equaling about one-third that of the abdominal region. Cranial bones finely granulated. Pelvic fins arising midway between the pectorals and the anal; dorsal and anal fins nearly equal in size, and the former arising opposite to the middle of the latter. Scales mostly smooth, but sometimes in part longitudinally striated, the striæ terminating in the coarse serrations of the posterior border which characterize the principal flank-scales; many of the flank-scales deeper than broad."

The distribution of this species is identical with that of its congener, and, like the latter, it is more abundant at Durham than elsewhere.

Genus Dictyopyge Egerton.

Distinguished from Catopterus only by the more anterior position of the dorsal fin, which never arises behind the origin of the anal.

Dictyopyge macrura W. C. Redfield.

1841. *Catopterus macrurus,* W. C. Redfield, Amer. Journ. Sci., vol. xli., p. 27.
1847. *Dictyopyge macrura,* Sir P. Egerton, Quart. Journ. Geol. Soc., vol. iii., p. 276, pl. viii., pl. ix., Fig. 1.
1857. *Catopterus macrurus,* W. C. Redfield, Proc. Amer. Assoc. Adv. Sci. 1856, pt. ii., p. 186.
1888. *Dictyopyge macrura,* J. S. Newberry, Monogr. U. S. Geol. Surv., vol. xiv., p. 64, pl. xviii., Figs. 1, 2.
1895. *Dictyopyge macrura,* J. S. Newberry, A. S. Woodward, Cat. Foss. Fishes Brit. Museum, pt. iii., p. 4, text-fig. 1.

A species attaining a total length of about 15 cm. Length of head with opercular apparatus somewhat less than the maximum depth of the trunk, and contained nearly five times in the total length of the fish; depth of caudal pedicle less than one-half of that of the abdominal region. Cranial bones externally ornamented with fine granulations. Pelvic fins arising midway between the pectorals and anal fin; dorsal at least as high as long, arising slightly in advance of the anal and nearly as large as the latter; anal with about 30 rays, and extending almost to the base of the caudal fin. Scales smooth, not serrated.

This species is not represented in New Jersey, being confined, so far as known, to the Triassic Coal-field of Virginia.

Family EUGNATHIDÆ.

Trunk fusiform or elongate, not much laterally compressed. Cranial and facial bones moderately robust, externally enameled, and opercular apparatus complete; gape of mouth wide, snout not produced, marginal teeth conical, and larger than the inner teeth. Fin-rays robust, articulated, and distally divided fulcra conspicuous. Dorsal fin short and acuminate. Scales rhombic, sometimes with rounded posterior angles.

Genus PTYCHOLEPIS Agassiz.

Trunk elegantly fusiform; snout acutely pointed and prominent; external bones highly ornamented with prominent ridges; marginal teeth very small and regular; dorsal fin in advance of anal, caudal fin forked; scales all narrow and elongate, marked with deep longitudinal grooves. Fulcra biserial, conspicuous on all the fins excepting the dorsal.

Ptycholepis marshi Newberry.

1878. *Ptycholepis marshi,* J. S. Newberry, Ann. N. Y. Acad. Sci., vol. i., p. 127.
1888. *Ptycholepis marshi,* J. S. Newberry, Monogr. U. S. Geol. Surv., vol. xiv., p. 66, pl. xix., Figs. 1, 2.
1895. *Ptycholepis marshi,* A. S. Woodward, Cat. Foss. Fishes Brit. Museum, pt. iii., p. 324.

A species of slender proportions, attaining a length of about 20 cm. Head with opercular apparatus occupying somewhat less than one-fourth the total length of the fish. Ornamental rugæ of cranial roof slightly radiating; those of the facial and opercular bones more or less parallel and forked. Dorsal fin far forwards, and pelvic fins arising opposite its hinder extremity. Scales exhibiting only longitudinal ridges and furrows, and the hinder border often deeply serrated. (Woodward).

No indications of this species have yet been discovered in New Jersey. The dozen or so examples which have been obtained were all derived from the Newark series of Durham, Connecticut.

Order CROSSOPTERYGII.

Family COELACANTHIDÆ.

Body deeply and irregularly fusiform, with cycloidal, deeply overlapping scales, more or less ornamented with ganoine. Branchiostegal apparatus between the mandibular rami consisting of a pair of large gular plates. Paired fins obtusely lobate; two dorsal fins, the anterior without baseosts, the posterior dorsal and the anal with baseosts, obtusely lobate. Axial skeleton extending to the extremity of the caudal fin, usually projecting and terminated by a small supplementary caudal. Air-bladder ossified.

Genus DIPLURUS Newberry.

Supplementary caudal fin prominent, with much elongated pedicle; fin-rays robust, closely articulated in the distal half; preaxial rays of the first dorsal and caudal fins with spinous tubercles. Scales and head-bones irregularly striated.

Diplurus longicaudatus Newberry.

1878. *Diplurus longicaudatus,* J. S. Newberry, Ann. N. Y. Acad. Sci., vol. i., p. 127.
1888. *Diplurus longicaudatus,* J. S. Newberry, Monogr. U. S. Geol. Surv., vol. xiv., p. 74, pl. xx.

The type and only known species, attaining a total length of about 70 cm. to the tip of the supplementary caudal fin, and maximum depth of trunk of about 20 cm. Anterior dorsal fin strong, supported by a single large laminar axonost; the lobate posterior dorsal nearly opposite the anal, and corresponding to it in form and size; caudal fin much elongated, and separated from the supplementary caudal by a distinct interval; paired fins obtusely lobate; scales large cycloidal, and deeply overlapping; the ex-

posed portion marked with fine longitudinal rugæ; teeth unknown.

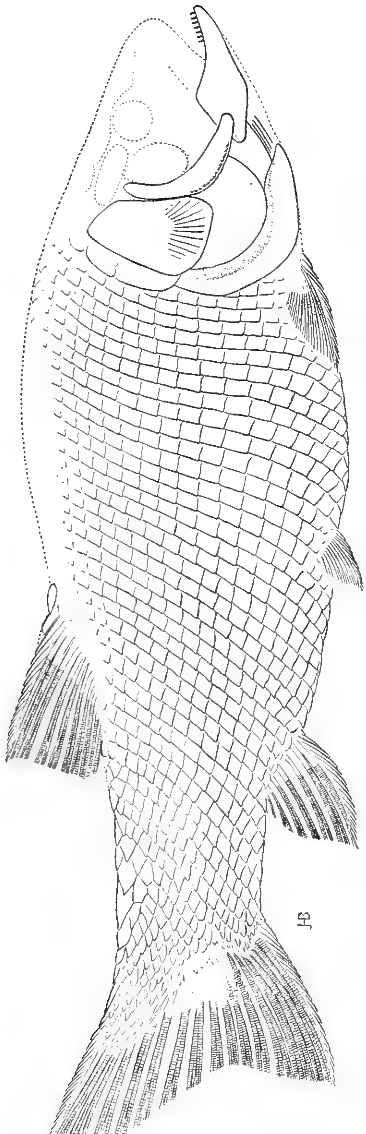
This large Crossopterygian is of extremely rare occurrence, being known only by five specimens, two of which were obtained from Boonton, and the remainder from Durham, Connecticut. All of these specimens are now preserved in the American Museum of Natural History, in New York.

Explanations of Plates.

PLATE I.

Semionotus agassizii (W. C. Redfield). Newark series; Sunderland, Mass. Lateral aspect of nearly perfect specimen belonging to the American Museum of Natural History, New York, $\times \frac{1}{2}$.

PLATE I.



Semionotus agassizii (Redf.) $\times$ ½.

PLATE II.

Fig. 1. *Semionotus fultus* (Ag.). Dorsal fin.
" 2. " " Pectoral fin.
" 3. " " Anterior flank scales.
" 4. " " Posterior flank scales.
" 5. *Semionotus agassizii* (W. C. Redf.). Scales from the twelfth longitudinal row, a little below the lateral line.
" 6. *Semionotus micropterus* (Newb.). Pectoral fin.
" 7. " " " Anterior flank scales.
" 8. " " " Posterior flank scales.
" 9. *Semionotus agassizii* (W. C. Redf.). Posterior flank scales showing "pegs."
" 10. *Semionotus agassizii* (W. C. Redf.). Hindermost scale of anterior dorsal ridge.
" 11. *Semionotus micropterus* (Newb.). Hindermost scale of anterior dorsal ridge.
" 12. *Semionotus agassizii* (W. C. Redf.). Scales of the seventh and eighth longitudinal rows, immediately below the lateral line.
" 13. *Semionotus micropterus* (Newb.) Dorsal fin.

All the figures of Plate II. are of twice the natural size, and drawn by Dr. G. F. Eaton from specimens belonging to the Yale Museum. (See American Journal of Science, vol. xv., April, 1003.)

PLATE II.

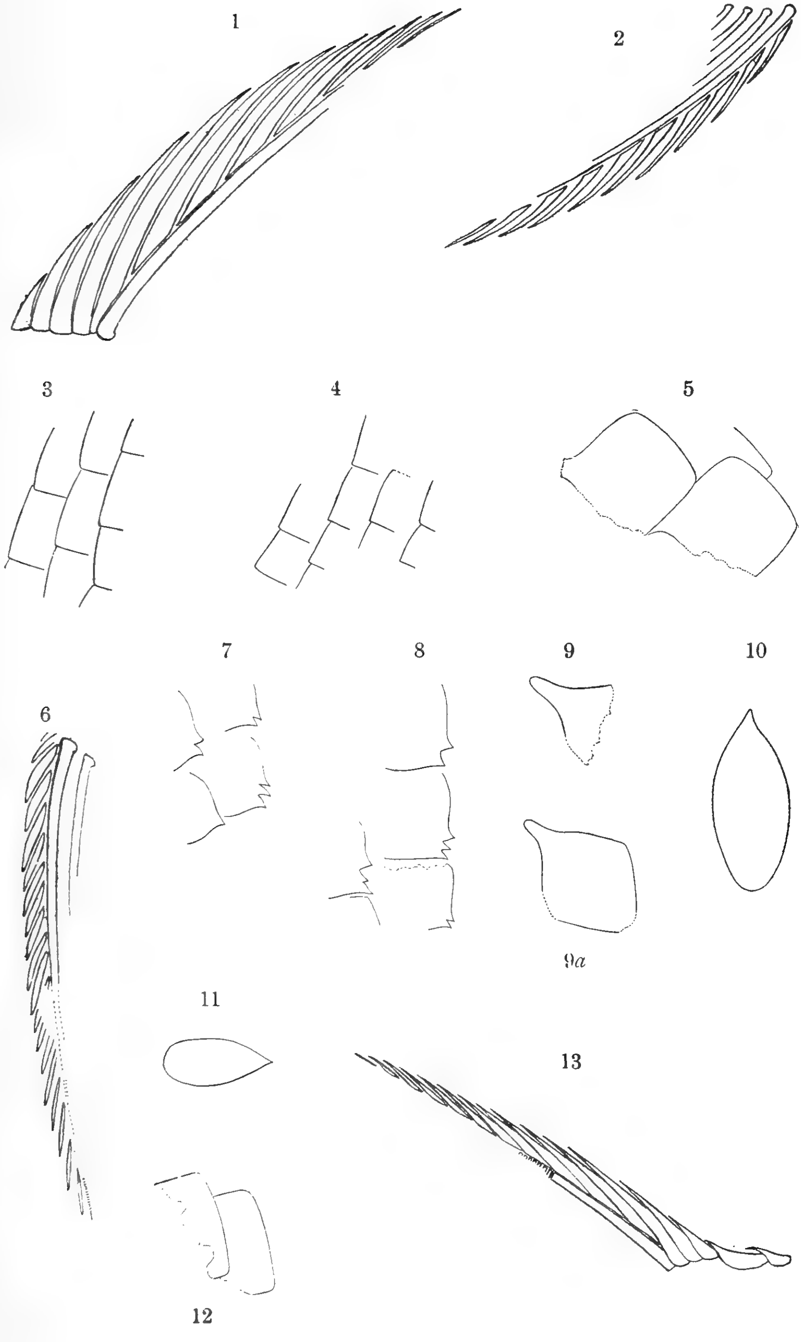


PLATE III.

Fig. 1. *Semionotus agassizii* (W. C. Redf.). Head, natural size.
Fr, frontal; *Pa,* parietal; *S.t,* supratemporal; *Sq,* squamosal; ***P.or,*** postorbital; *Op,* operculum; *P.op,* preoperculum; *I.op,* interoperculum; *S.op,* suboperculum.

" 2. *Seminonotus agassizii* (W. C. Redf.). Lower flank scale, showing articular process or "peg," natural size.

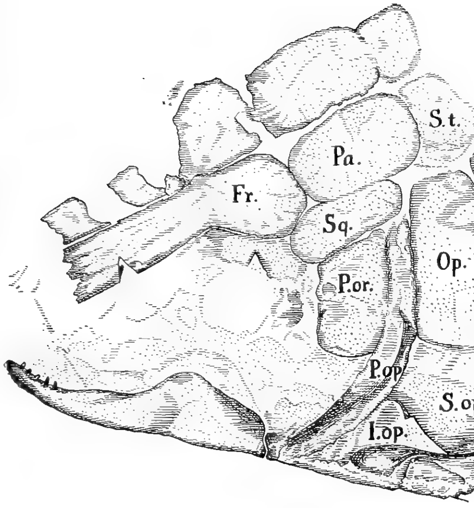
" 3. *Semionotus* sp. Lower flank scales, showing double articulation. $\times 4/1$.

" 4. *Semionotus* sp. Premaxillæ, natural size.

" 5. *Semionotus ovatus* (W. C. Redf.). Dorsal fin, twice natural size.

All the figures of this plate are reproduced after Eaton, *loc cit.,* (1903).

1



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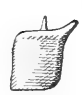

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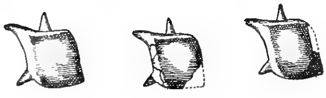

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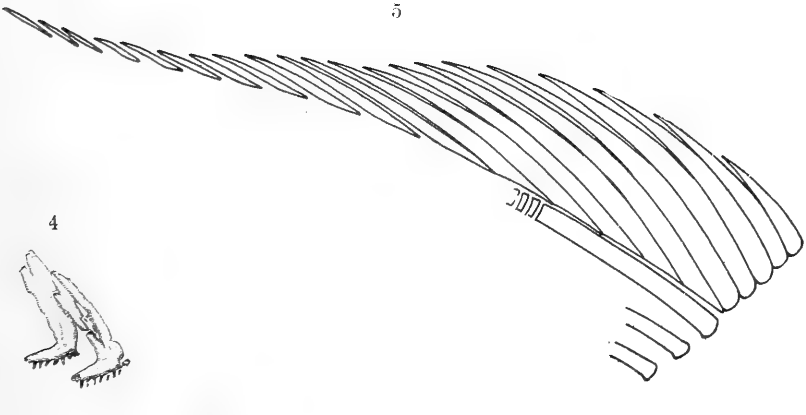


4

PLATE IV.

Semionotus ovatus (Redf.), $\times$ $^{6}/_{7}$.

Small-sized, somewhat distorted individual from Boonton, N. J. State Geological Collection.

PLATE V.

Semionotus ovatus (Redf.). Natural size.

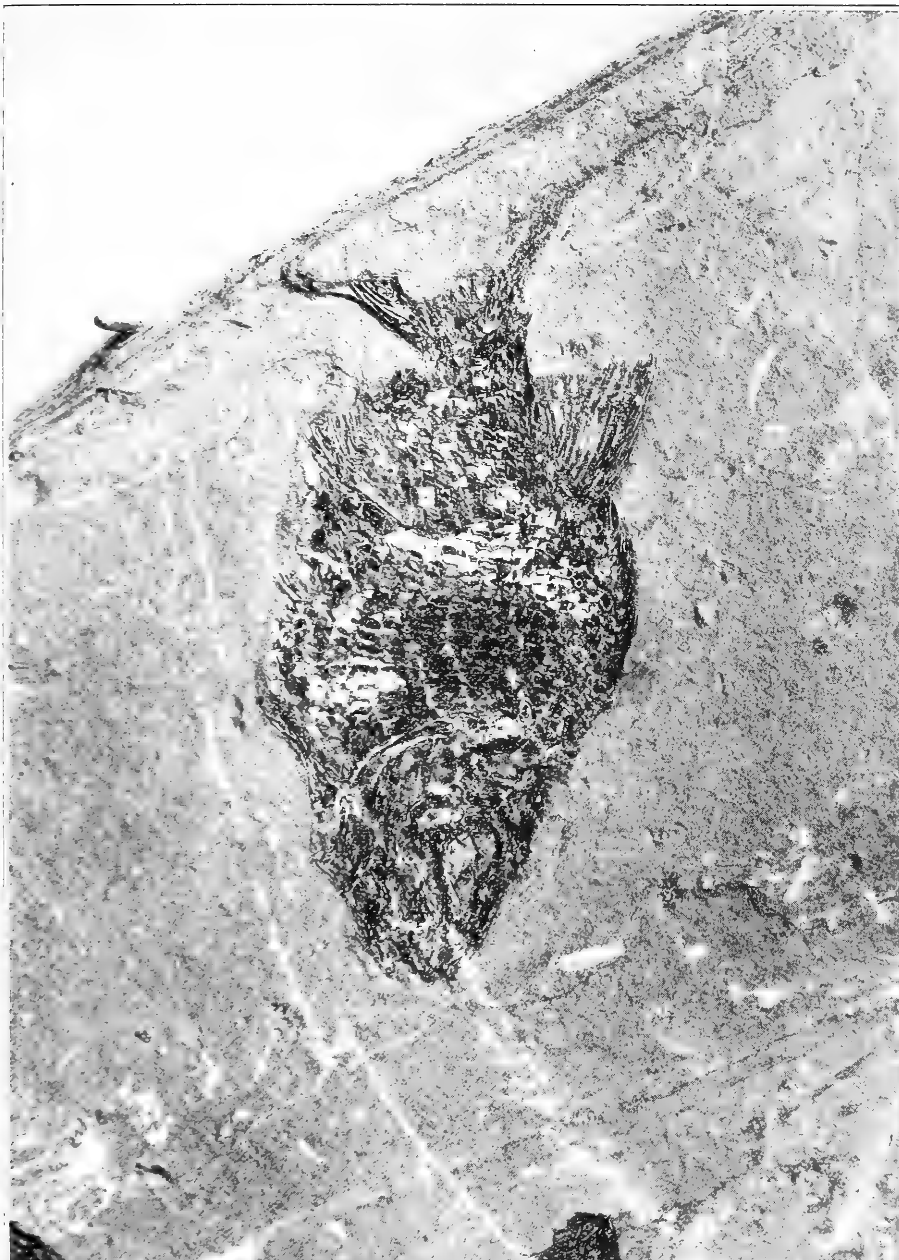
Imperfect specimen from the Newark series of Boonton, showing characters of the median fins. State Geological Collection.

PLATE VI.

Semionotus ovatus (Redf.). Natural size.

Young individual, apparently belonging to this species, similar to those to which the name *"Isctypterus beardmorei"* has been applied. Newark series; Boonton, N. J. Original belonging to the State Geological Collection.

PLATE VI.



SEMIONOTUS OVATUS (Redf.). Immature example. 1/1.

PLATE VII.

Semionotus agassizii (Redf.). Natural size.

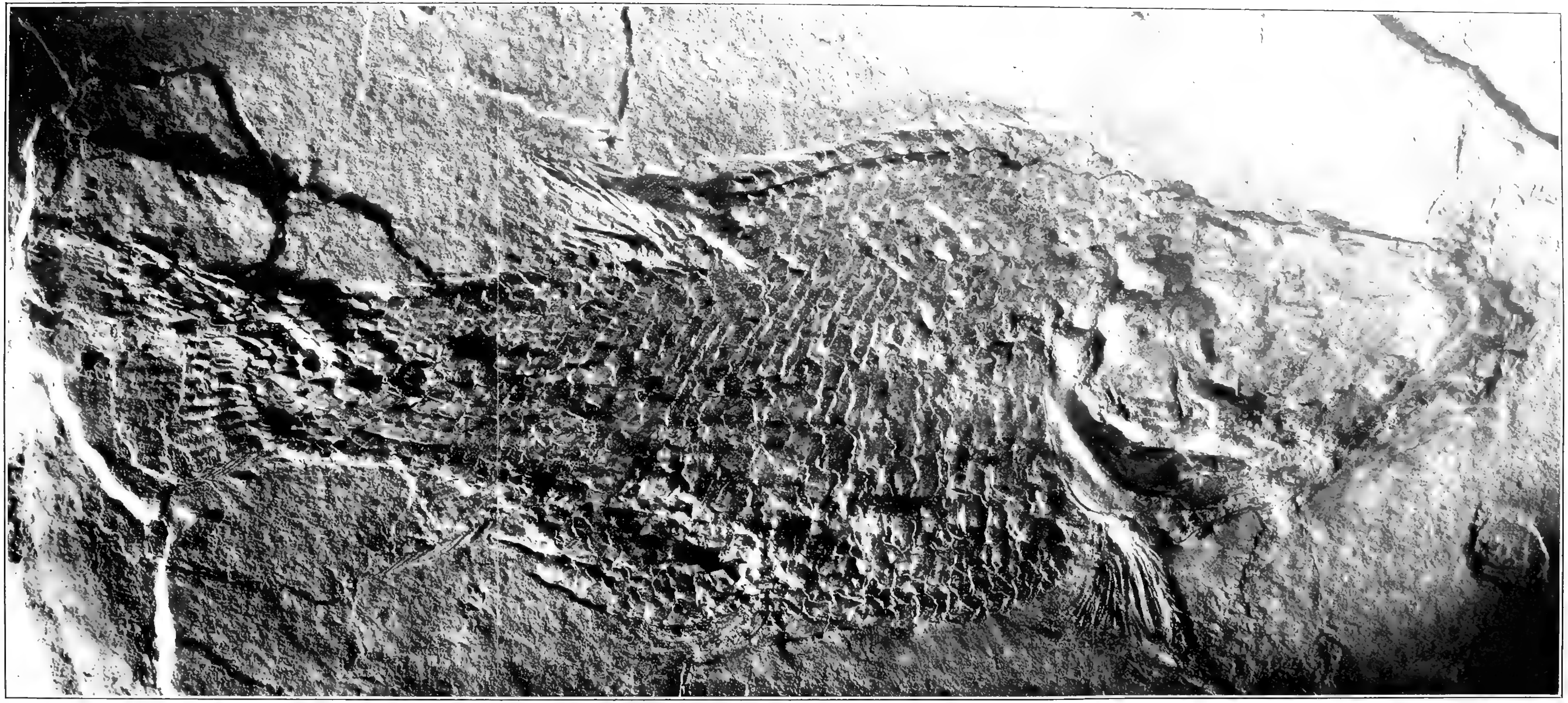
Nearly perfect fish from the Newark series of Sunderland, Massachusetts, determined by Professor Newberry as belonging to this species. An outline figure of the same specimen is shown of one-half the natural size in Plate I. Original preserved in the American Museum of Natural History in New York.

Semionotus agassizii (Redf.), × 1/1. Sunderland, Mass.

PLATE VIII.

Semionotus agassizii (Redf.). Natural size.

Photographic reproduction of a specimen from the same locality as the last, and, like it, belonging to the American Museum of Natural History in New York. Dorsal contour and ridge-scales well displayed.

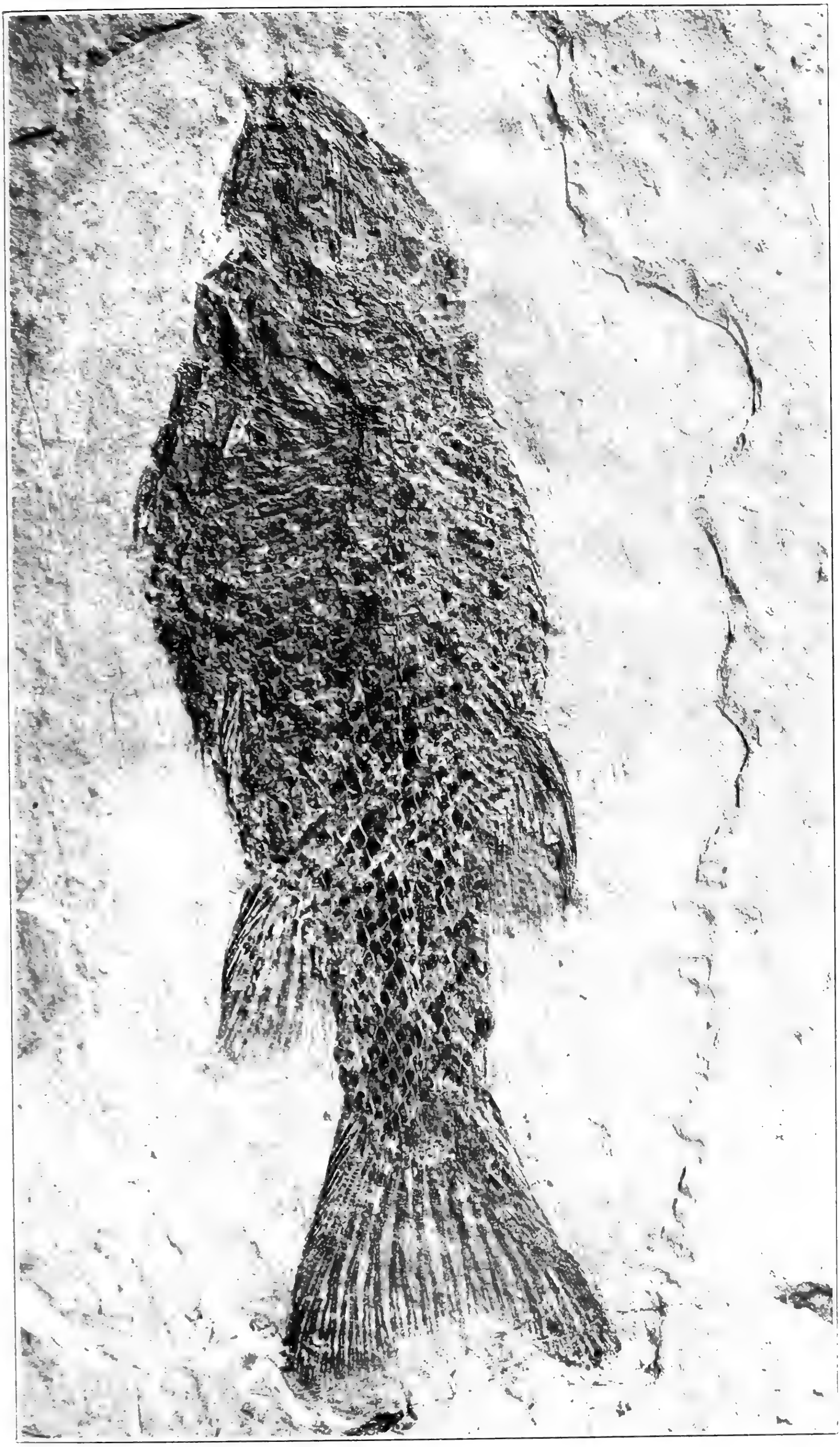


SEMIONOTUS AGASSIZII (Redf.), 1/1. Sunderland, Mass.

PLATE IX.

Semionotus fultus (Agassiz). Natural size.

Photographic reproduction of the original specimen figured in Plate VI, Fig. 2, of Newberry's Monograph (1888), now preserved in the American Museum of Natural History in New York. (Cat. No. 602*G*). Boonton, N. J.



SEMIONOTUS FULTUS (Ag.), × 1/1. Original figured by Newberry.

PLATE X.

Semionotus lineatus (Newb.) $\times {}^{8}/_{11}$.

Imperfect specimen displaying characters of the dorsal and anal fins, and showing ossified ribs. Newark series; Boonton, N. J. Original belonging to the State Geological Collection.

PLATE X.

Semionotus lineatus (Newb.), × 8/11.

PLATE XI.

Semionotus lineatus (Newb.) $\times$ $^1/_1$.

Fragment with the dorsal fin excellently preserved, and showing anteriorly notched dorsal ridge-scales. Newark series; Boonton, N. J. Original belonging to the State Geological Collection.

PLATE XII.

Semionotus elegans (Newb.). Natural size.

Photographic reproduction of the original specimen figured in Plate XIV, Fig. 1, of Newberry's Monograph (1888), now preserved in the American Museum of Natural History in New York. (Cat. No. 1516*G*.) Newark series; Boonton, N. J.

PLATE XII.

SEMIONOTUS ELEGANS (Newb.). Natural size.

PLATE XIII.

Catopterus gracilis (Redf.). Natural size.

Specimen of less than the average size, but with well preserved squamation, from the Connecticut Valley Trias. Original belonging to the Museum of Comparative Zoölogy, at Cambridge, Massachusetts.

PLATE XIV.

Examples of *Semionotus* showing effects of mechanical deformation, one of them being compressed, and the other elongated, by a force acting in a single direction. Newark series; Boonton, N. J. Original belonging to State Geological Collection.

PLATE XIV.

Mechanically distorted examples of SEMIONOTUS.